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EXTRADURAL SPINAL TUMORS—PRIMARY, SECONDARY, METASTATIC[1]

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THE GROUPING AND HISTOLOGICAL STRUCTURE OF THE ENCAPSULATED TUMORS OF THE SPINAL CORD AND MEMBRANES

IT is useful to group spinal cord tumors into those outside of the dura mater—the extradural—and those inside of that membrane—the intradural—and still further to divide the intradural growths into the extramedullary and the intramedullary.

The technical improvement in the operative precedures for the exposure and removal of extramedullary tumors—in which the dura is first incised without injury to the arachnoid—has made it possible to demonstrate at the operating table that some of these growths lie entirely outside of and others inside of the arachnoid.

Intradural extra-arachnoid growths may be attached to the inner surface of the dura or only to a nerve root, and those within the arachnoid may be adherent only to that membrane, to a spinal nerve root or, rarely, only to the pia mater. A growth attached to a nerve root but otherwise free within the arachnoid cavity may be a true meningeal tumor with an assumed origin from the expansion of the leptomeninges over the root, and one presumably derived from the perineurial connective tissue sheath of a spinal nerve root may be adherent to the dura without any visible connection with any part of the root.

Similar variations may be met with in extradural spinal tumors; a growth of meningeal origin may be attached to a nerve root or a tumor derived from the sheath of a nerve root may be, grossly, adherent only to the dura.

The efforts made by many investigators to classify the encapsulated tumors of the nervous system from the standpoint of their microscopic structure have resulted in a wide variety of conclusions regarding their nature and origin, and it is therefore not surprising that there is a diversity of opinion regarding the histological features of tumors of the spinal cord.

Antoni, in his monograph on "Rueckenmarkstumoren und Neurofibromatose" uses the terms endothelioma and neurofibroma or neurinoma for the two most common varieties of spinal tumor. On account of a lack of agreement concerning the pathological nature of the meningeal tumors which were variously classified as endotheliomata or sarcomata, Cushing suggested the name "meningioma." This term is descriptive of certain intracranial dural growths, but if spinal tumors adherent only to the dura were called by the same name, the so-called neurofibroma which is sometimes attached only to the dura might, from its gross appearance, be called a meningioma.

Mallory proposed the name "arachnoid fibroblastoma" for the tumor commonly called endothelioma and "perineurial fibroblastoma" for the so-called neurofibroma. According to Mallory there is no true endothe-

[1] Read at the combined meeting of the New York Neurological Society and the Section of Neurology of the New York Academy of Medicine, November 1, 1927.

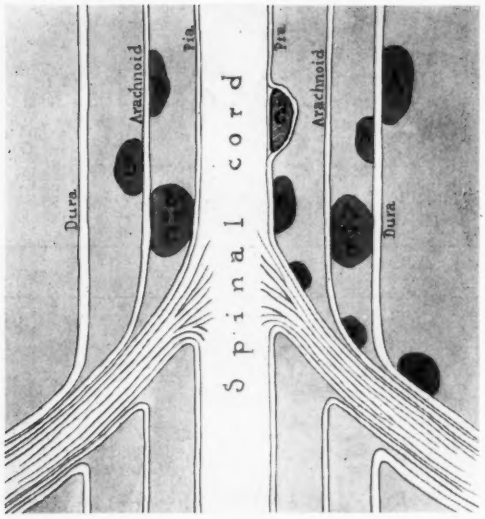


Fig. 1. The locations in relation to the three membranes, in which we have found spinal meningeal fibroblastomata (endotheliomata). *A*, Tumors adherent to dura; *B*, tumors adherent to arachnoid; *C*, tumors adherent to pia; *A'*, *B'*, *C'*, tumors on nerve root. *C''* (crosshatched) indicates a subpial location which we have never encountered. (Diagrammatic.)

lium on the inner surface of the dura, the inner layer of which is composed of flattened fibroblasts. He proposed the name "arachnoid fibroblastoma" in order to indicate that the growth originates from, and reproduces the general structure of, the arachnoid villi.

Mallory studied mainly the cerebral tumors removed by Cushing, and in these naturally it was impossible to determine either at the operation or under the microscope, the degree of intimacy of relation between the new-growth and the arachnoid.

The conditions within the vertebral canal are favorable for the elucidation of this question. In some of our spinal meningeal tumors we have found the arachnoid entirely free from the growth, so that a neoplasm adherent to the inner surface of the dura could be raised up from the grossly normal arachnoid as soon as the dura had been incised and the cut edges retracted.

In spite of the researches of Harvey and Burr which seemed to show an ectodermal origin of at least part of the meninges, the preponderance of evidence supports the view that the membranes are developed from groups of cells in the perimedullary mesenchyme. It is very probable that the tumors variously called endotheliomata, meningiomata, or arachnoid fibroblastomata, are derived from cells which were normally destined to form part of the arachnoid but which remained with the cell groups which finally differentiated into the cells of the dura mater. The occasional occurrence of both intracranial and spinal *extradural* tumors of the typical "endothelioma" structure support such a viewpoint (Fig. 1).

In addition to the ordinary staining methods, Penfield used those of Cajal and Del Rio-Hortega. In a study of the spinal tumors removed in our clinic, he has recently shown that there are distinct histological differences between the three main types of benign encapsulated tumors of the nervous system,—the "meningeal fibroblastoma" (endothelioma, meningioma, arachnoid fibroblastoma), the "perineurial fibroblastoma" derived from a spinal nerve root or peripheral nerve (solitary neurofibroma, neurinoma), and the "neurofibroma of von Recklinghausen's disease." According to Penfield, "although the first two varieties are fibroblastic, they are easily distinguished from each other microscopically because each retains the morphological characteristics of the specialized connective tissue from which it arises. Only in the last group is nervous tissue to be found."

The terminology used by Penfield—meningeal fibroblastoma, perineurial fibroblastoma, neurofibroma of von Recklinghausen—is, I think, the best that has been hitherto proposed. The differentiation of the von Recklinghausen tumors from the solitary perineurial fibroblastomata constitutes an important advance in the histological classification of encapsulated tumors of the nervous system. The term "meningeal fibroblastoma" is a happy one, because, grossly, the tumors of this type may be attached to any of the three membranes (see Fig. 1). It is possible that these growths may be derived from dislocated mesenchymal arachnoid cells, grouped with either pia or dura mater.

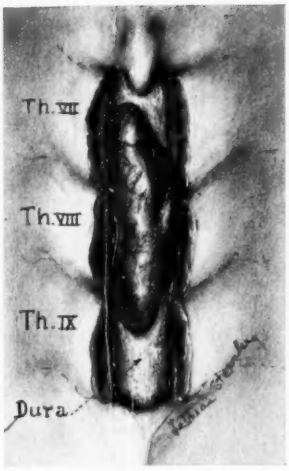


Fig. 2.

Fig. 2. Case 17 (N. I. A 11962). Showing the appearance upon its exposure of an extradural meningeal fibroblastoma (see Fig. 3).

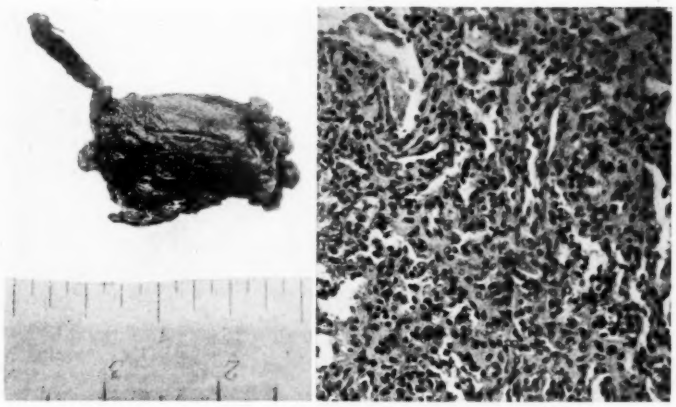


Fig. 3.

Fig. 3. Case 17. Photograph and photomicrograph showing the tumor and its structure. (H. and E. stain. × 220).

The Frequency and Clinical Features of Extradural as Compared with Intradural Tumors

Table I includes all of the extradural and intradural tumors, exclusive of intramedullary and metastatic extradural growths, operated upon in my clinic to September, 1927.

TABLE I.—EXTRADURAL AND INTRADURAL TUMORS OPERATED UPON TO SEPTEMBER, 1927

	Extradural	Intradural	Total
Meningeal fibroblastoma (endothelioma, meningioma, arachnoid fibroblastoma)	3	72	75
Perineurial fibroblastoma (neurofibroma, neurinoma)	5*	37*	42
Neurofibroma of von Recklinghausen's disease	2*	5*	7
Fibroma	1	3	4
Sarcoma	17	8	25
Chondroma	11	0	11
Lipoma	1	3	4
Angioma	2	1	3
Chordoma	2	0	2
Ependymoma	0	1	1
Leiomyoma	0	1	1
Tuberculoma	1	0	1
Dermoid	0	1	1
Ganglion neuroma	1	0	1
Neuroblastoma	0	1	1
Total	46	133	179

*In one case there were both extradural and intradural tumors.

Thus, excluding intramedullary and metastatic growths, 46 or 26 per cent were extradural and 133 or 74 per cent were intradural. The meningeal and perineurial fibroblastomata formed a large proportion of the tumors inside of the dural sac, but they were much less frequent outside of that membrane (82 per cent of intradural and 17 per cent of extradural growths), while the sarcomata and chondromata which formed 61 per cent of the extradural tumors were comparatively rare inside of the dura (6 per cent of intradural extramedullary growths were classified as sarcomata).

A clearer idea of the relative frequency of the most common extradural and intradural growths can be gained from Table II.

TABLE II.—PERCENTAGE OF FREQUENCY OF THE MOST COMMON EXTRADURAL AND INTRADURAL TUMORS IN A SERIES OF 179 CASES. (INTRAMEDULLARY AND METASTATIC GROWTHS NOT INCLUDED.)

	Extradural per cent	Intradural per cent	All tumors per cent
Meningeal fibroblastoma	7	54	42
Perineurial fibroblastoma	11	28	23
Sarcoma	37	6	14
Chondroma	24	0	6
Neurofibroma (von Recklinghausen)	4	4	4
Fibroma	2	2	2
Lipoma	2	2	2

Fig. 4.

Fig. 4. Case 20. (N. I. A 13144). Showing an extradural perineurial fibroblastoma exposed at operation. (See Fig. 5.)

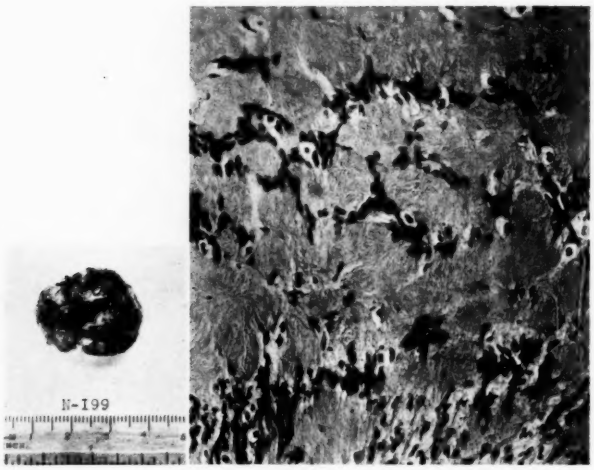


Fig. 5.

Fig. 5. Case 20. Photograph and photomicrograph showing the tumor and its structure. (H. and E. stain. × 150).

The increase in size of the intradural meningeal and perineurial fibroblastomata, which form 82 per cent of these growths, is a slow and gradual one and in most instances the signs of interference with cord function advance slowly. These growths are more infrequent outside of the dura (17 per cent of our series of extradural tumors). On the other hand, the sarcomata, which are rarely intradural, grow more rapidly and either make pressure upon the dura early, or more or less suddenly extend into the vertebral canal through intervertebral foramina or by bone destruction. Not so rarely, secondary and metastatic extradural growths cause an acute softening of the spinal cord at the affected level through interference with its blood supply.

In this connection mention must be made of another fact which we have found in the study of our extradural tumors. The perineurial fibroblastomata and the neurofibromata of von Recklinghausen's disease as well as the relatively infrequent extradural angiomata usually cause slowly progressive cord disturbances, while the symptoms due to *extradural* meningeal fibroblastomata progress much more rapidly. In the three cases of our series the interval between the first symptom and marked cord symptoms was 7, 7, and 1½ months, or an average of 4½ months.

For all of these reasons, the course of spinal cord symptoms in extradural tumors is often more rapidly progressive. Although, in many extradural tumors the signs and symptoms of cord involvement progress slowly and in some intradural growths the advance is rapid, still, all in all, a short history must make one suspect that the neoplasm is outside of the dura.

Radicular pain as an early symptom does not occur as often in extradural expanding lesions because of the relatively smaller number of instances in which the growth begins in the sheath of or in close apposition to a nerve root. Not so rarely, due to the interposition

Fig. 6.

Fig. 6. Case 15. (N. I. A 9905). Showing two extradural perineurial fibroblastomata exposed at operation. (See Fig. 7.)

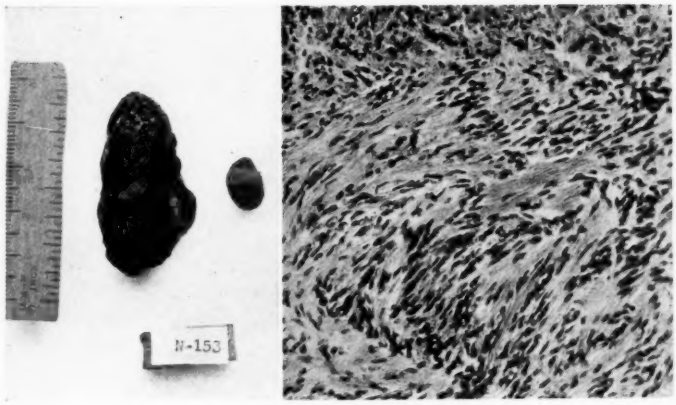


Fig 7.

Fig. 7. Case 15. Photograph and photomicrograph showing the two tumors and their structure. (H. and E. stain. × 150.)

of the firm dura and of a "buffer" of cerebrospinal fluid, the early spinal cord disturbances have a vague and indefinite character. Sudden exacerbations of signs and symptoms occur relatively often, and a flaccid paraplegia occurring within a few days of the onset of weakness of the limbs is seen almost exclusively in malignant extradural disease.

Contralateral motor disturbances, contralateral paræsthesias in the lower extremities and the "reverse" Brown-Séquard syndrome (most marked motor disturbances on the opposite side and most advanced sensory diminution on the same side as the tumor) are more often observed in extradural growths.

Changes in the bony structures, visible on the X-ray films, occur in more than one-half of all extradural tumors, although, in some instances, considerable bone destruction is seen at the operation which was not apparent on the X-rays. These bony changes are either an enlargement of the vertebral canal (best seen in lateral stereoscopic views of the spine), a localized defect in one or more vertebræ, a scoliosis at or above the location of the disease, an actual shadow of the new-growth, or finally a sinking together of the bodies of several vertebræ. In intradural growths bony changes in the X-rays occur rarely except in the so-called giant tumors of the conus and cauda equina in which an enlargement of the vertebral canal is usually clearly seen on the X-ray films. Occasionally, there is a localized arthritis of the vertebræ at the general level of the intradural new-growth.

With some exceptions that will be described later on (very small growths such as the ven-

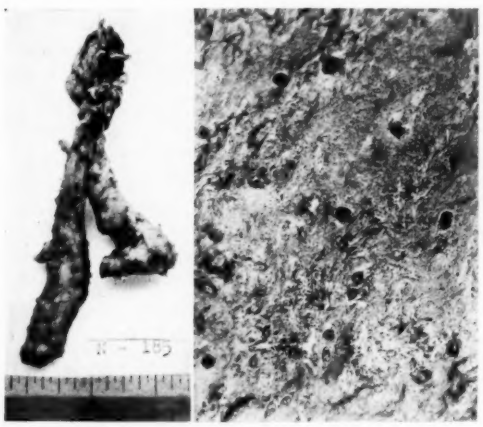


Fig. 8 (left). Case 18 (N. I. A 12490). Showing a chondroma of unusual form removed from the ventral aspect of the dura (see Fig. 9).

Fig. 9. Case 18. Showing the structure of the tumor (Mallory's phosphotungstic acid stain. × 110).

Fig. 10.

Fig. 10. Case 7. (M. S. H. 220312). Photograph and photomicrograph showing an encapsulated extradural angioma (see also Fig. 11).

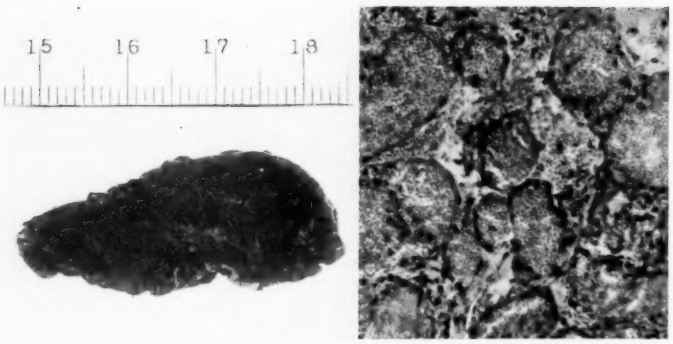


Fig. 11.

Fig. 11. Case 7. Showing the tumor and its structure. (H. and E. stain. × 150—Path. Lab., M. S. H.)

tral chondromata derived from an intervertebral disc, etc.) the manometric studies of the spinal fluid have demonstrated a more or less marked spinal subarachnoid block. The fluid obtained by lumbar puncture was often yellow in color[1] and contained an excess of globulin or total protein, although the figures of protein increase were never as high as in intradural cord compression (*vide infra*).

After spinal fluid had been withdrawn by lumbar puncture, a distinct and often very marked increase in the subjective and objective signs of cord disturbance was often observed. Oppenheim, Newmark, and others once warned of the danger of increase of symptoms after lumbar puncture, but they made no statement whether this occurred more often in extradural or in intradural growths. In a paper published in 1922, we called attention to the diagnostic significance of such an increase of symptoms, and stated that it is especially frequent in extradural tumors and in some intradural growths adherent to the dura.

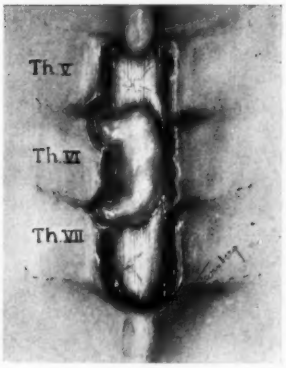
[1] The fact that xanthochromia occurs with extradural tumors makes it certain that the yellow color is not due to substances from the tumor itself, as was once suggested by Cushing; nor is the view expressed by German writers that the yellow color is due to concentration of the fluid, tenable. We have attempted, without success, to bring about a xanthochromia by concentration of spinal fluids by slow evaporation over a water bath. It is most probable that in cord compression xanthochromia is due to blood pigments from congested spinal veins (Meztrezat, Ayer, etc.).

In both extradural and intradural tumors adherent to the dura, indefinite level signs not rarely become distinct, and motor and sensory disturbances more marked after fluid has been withdrawn from the lumbar subarachnoid space. A careful neurological examination should, therefore, always be made not only before but also after the puncture.

If the history of the illness is a short one (4 to 8 months) and there are bone changes visible in the X-ray films, an increase of signs after the removal of fluid by lumbar puncture usually means that there is an extradural tumor. If, on the other hand, there is no X-ray evidence of bone destruction and the clinical history one of slow progression, the only conclusion that can be drawn from an increase of symptoms after lumbar puncture is that a growth—either extra- or intradural—is adherent to the dura.

The Classification of Extradural Spinal Tumors; the Symptoms of Primary, Secondary and Metastatic Growths

Primary, secondary, and metastatic extradural growths within the cranial cavity are relatively infrequent as compared with tumors of the brain itself or of cranial nerves or membranes, and it is rarely difficult to distinguish between the one and the other.



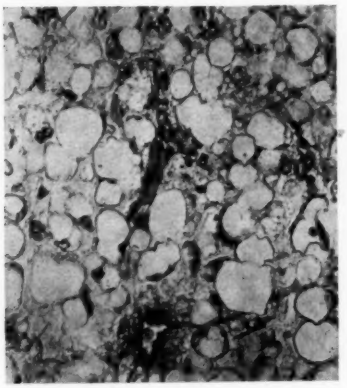


Fig. 12 (left). Case 22 (M. S. H. 279954). Showing appearance at operation presented by an extradural lipoma (see Fig. 13).
Fig. 13. Case 22. Showing the structure of the tumor which consists of embryonal fat tissue. (H. and E. stain. × 420—Path. Lab., M. S. H.)

The conditions are different in the vertebral canal. Compression of the spinal cord by tumors not derived from cord, roots, or membranes is of frequent occurrence, and it is therefore especially necessary to group spinal growths according to their location and the structures from which they originate. In other words, a large number of extradural spinal tumors begin in the bony framework of the spine or in the soft tissues which surround the bone; they may be primarily within the vertebral canal or may only secondarily invade the extradural space. The histological structure of these growths is naturally subject to many variations.

The classification of extradural new-growths without adequate differentiation between those that are *primarily* extradural and those that *secondarily* extend into the vertebral canal has led to some confusion. Vertebral tumors are often but not always considered apart, but not a few growths that originate from the bony or cartilaginous framework of the spine are, both in their location and their mechanical effects, "primary extradural" tumors. On the other hand, benign and malignant tumors often extend into the vertebral canal at a late period of their growth, and they may never affect the dura or the nervous structures within the dural sac.

Most of the tumors that cause cord or root symptoms do so by direct pressure; some by interference with the blood supply and a secondary myelomalacia; in still other cases the interference with cord function is due to a sinking together of the bodies of several vertebræ and not to the direct pressure of the neoplasm.

Aside from the grouping of extradural tumors according to their histological structure, a classification of these growths based upon their time relation to the vertebral canal is necessary, if the variations in their clinical course are to be understood. From this viewpoint, extradural tumors may be divided into (1) primary extradural, (2) secondary extradural, (3) metastatic extradural. Of the 46 cases in our series of extradural growths (not including the metastatic tumors) 24 or 52 per cent were primary, and 22 or 48 per cent were secondary.

1. *Primary extradural spinal tumors:*
   a. Growths that arise from the dura, nerve roots, or epidural fat and blood vessels and are located entirely within the vertebral canal.

   The most common forms histologically are:
   - Meningeal fibroblastoma
   - Perineurial fibroblastoma
   - Sarcoma
   - Chondroma
   - Lipoma
   - Angioma
   - Fibroma
   - Neurofibroma of von Recklinghausen's disease.

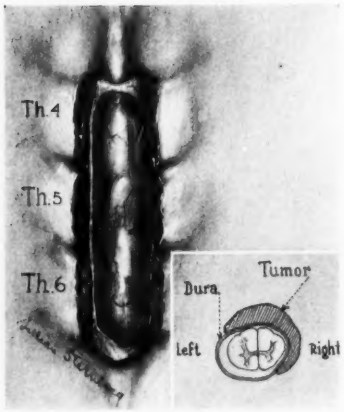


Fig. 14.

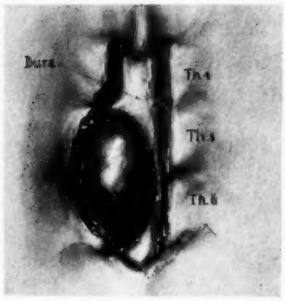


Fig. 15.

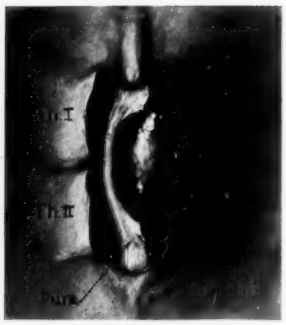


Fig. 16.

Fig. 14. Case 9 (N. I. 24766). Showing the appearance, at operation, of a primary extradural sarcoma.

Fig. 15. Case 14 (M. S. H. 261881). An extradural meningeal fibroblastoma as exposed at operation. Note the similarity to Fig. 16.

Fig. 16. Case 13 (N. I. A 4933). Showing a perineurial fibroblastoma exposed at operation in which it was difficult to state whether or not the growth was primarily extradural.

b. Growths that arise from the walls of the vertebral canal—the ligaments, intervertebral cartilages, and the bone, and lie entirely within the vertebral canal.
The most common forms are:
Chondroma of an intervertebral disc
Sarcoma
Osteoma.

2. *Secondary extradural spinal tumors:*
Growths from structures outside of the vertebral canal which secondarily invade the extradural space.
Sarcoma of the soft tissues of the back or thorax, or of the bony spine.
Chondroma of a vertebra.
Chordoma.
Ganglion neuroma
Hydatid cyst.

3. *Metastatic extradural spinal tumors:*
Carcinoma—most often from breast, thyroid, prostate, or gastro-intestinal tract.
Sarcoma and lymphosarcoma
Hypernephroma
Myeloma
Lymphoma of Hodgkin's disease.

There are inherent possibilities of error in this classification. Some tumors derived from bone or cartilage which would be included in the "primary" group, may have begun within the substance of these tissues before they extended into the vertebral canal and they might, therefore, actually belong to the "secondary" growths; likewise, a tumor classified as "secondary" may have begun in the vertebral canal before it invaded the extravertebral tissues and therefore was actually a primary extradural growth. With this reservation, the above classification should avoid some of the confusion regarding the symptoms and course of extradural tumors that has occurred in the past.

1. PRIMARY EXTRADURAL TUMORS

a. From dura, nerve roots, or epidural fat and blood vessels. With the exception of some of the dural sarcomata which are not well encapsulated, most of the growths in this group arise from dura or nerve roots, and have a good capsule. In size and in gross appearance they are very like the typical intradural extramedullary growths—2 to 4 centimeters in length and 1 to 2 centimeters in width, and often loosely adherent to the surface of the dura (Figs. 3A, 5A, 11A). As in the intradural growths, they are most often found on the posterior or lateral aspects of the dural sac. The tumors are usually single meningeal fibroblastomata (Figs. 2 and 3),[1] perineurial

[1] With the exception of Figures 11 and 13, the slides from which the photomicrographs were taken and the photographs of the tumors were prepared in the Laboratory of Neurocytology, Presbyterian Hospital, under the direction of Dr. Wilder G. Penfield, to whom I am indebted for the careful studies of our tumor material by differential staining methods.

fibroblastomata (Figs. 4 and 5), fibromata, angiomata, or lipomata.

In one instance (Figs. 6 and 7) there were two distinct perineurial fibroblastomata adherent to the dura but not grossly connected with any nerve root, but if more than one tumor is met with, one must think rather that the growths are neurofibromata of von Recklinghausen's disease, in which multiple encapsulated growths both outside of and within the dural sac are frequent.

One chondroma included in this group was well encapsulated and loosely adherent to the dura. The tumor was of bizarre shape; it lay on the ventral aspect of the dural sac not connected with bone or intervertebral cartilage and was loosely attached to the dura (Figs. 8 and 9). This one chondroma is included in this group because it was entirely different from the ventral chondromata derived from an intervertebral disc and from the secondary extradural chondromata to be described in another part of this paper.

In two patients, encapsulated tumors loosely attached to the dura had the gross appearance of extradural meningeal fibroblastomata, but histologically the growth was made up of a mass of small blood vessels with no microscopic evidence of the type structure of the meningeal fibroblastoma (Figs. 10 and 11). Extradural lipomata are rare, and there was only one example in our series. In this patient the growth was part of a generalized lipomatosis—an *adenolipomateuse symmétrique*—and the microscopic study (Klemperer) demonstrated that the growth consisted of embryonic fat tissue (Figs. 12 and 13).

The average length of time that elapsed before there were more or less well marked motor and sensory cord disturbances was between 16 and 17 months, but there was considerable variation, in this respect, between the different varieties of new-growth.

In the fibromata, perineurial fibroblastomata and the angiomata, the average period from first symptom to operation was 27 months; in the primary chondromata it was only 13 months, and in only 2 of the 7 patients was the history of more than 1 year's duration. The course of the extradural meningeal

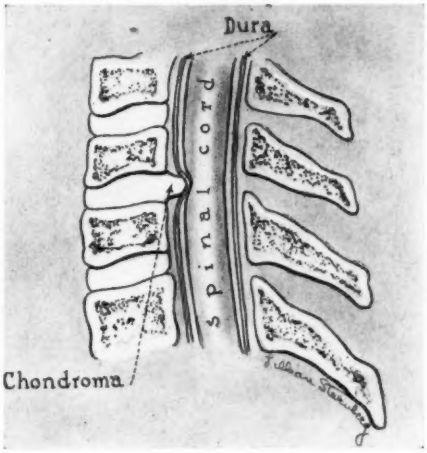


Fig. 17. Showing the usual location of a ventral vertebral disc chondroma.

fibroblastomata in our series was a remarkably rapid one, with an average of only 4½ months from the beginning of symptoms to the time of marked cord involvement.

In many of these patients, the clinical picture was so similar to that of an intradural tumor that the diagnosis "extradural tumor" could only rarely be made with any degree of certainty. The course of the comparatively infrequent primary dural sarcomata may also be slowly progressive. A more or less prolonged period of pain in the back not characteristically radicular in character, followed by rapidly advancing signs of disturbance of cord function are, however, outstanding clinical features of secondary and metastatic extradural tumors.

In the benign encapsulated growths increase of cord symptoms after withdrawal of fluid by lumbar puncture occurred in almost one-half of the patients, no matter whether the manometric tests showed a complete or only a partial spinal subarachnoid block. If the records in many of our earlier and some of our later cases were complete, the percentage would be a much higher one, probably 75 per cent. Xanthochromia does not occur so often as in intradural tumors, and the increase of globulin or of total protein was never so high as in intradural growths. In

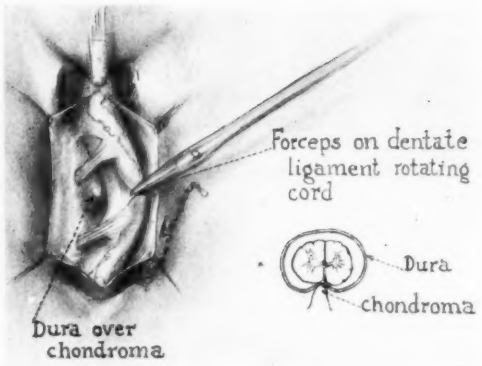


Fig. 18 (left). Case 10 (N. I. 26954). Showing the appearance at operation of a vertebral disc chondroma underneath a cervical spinal root.
Fig. 19. Case 23 (M. S. H. 281013). The appearance at operation of a vertebral disc chondroma.

most of the cases, the total protein was 50 to 60 milligrams, or only slightly above the normal, and the highest protein content was 150 milligrams. In one patient, with an extradural fibroma, the spinal fluid was normal in all respects.

The *primary* extradural sarcomata occur in two distinct forms. In one variety, the tumor is encapsulated, more or less firmly attached to the outer surface of the dura, does not become adherent to the walls of the vertebral canal, and rarely extends outward through intervertebral foramina. The predominant character of this form of extradural sarcoma is to extend along the surface of the dura and especially to more or less completely surround the dural sac. Not rarely there is a large amount of tumor tissue on the ventral aspect of the dura. The upper and lower limits of these growths can often be exposed by the removal of the arches of 2 or 3 vertebræ and the firm, reddish-brown tumor can usually be peeled off from the dura (Fig. 14), perhaps with a layer of that membrane. In some instances a growth that from its gross character appears to be a sarcoma, is found on microscopical examination to be a meningeal fibroblastoma (endothelioma). In 2 of our cases, the growths were very cellular, and did not contain the typical whorls (Fig. 15).

Some primary extradural sarcomata, although well encapsulated, extend along the dura for a considerable distance, so that their upper and lower limits can not be exposed at the operation, and they may, as in one case of our series, extend from the cervical to the lumbar regions (diffuse sarcomatosis of the dura). These extensive growths retain the characteristic that they do not become adherent to the walls of the vertebral canal.

The second variety of primary extradural sarcoma occurs as a well-encapsulated tumor which extends beyond the confines of the vertebral canal through intervertebral foramina or by bone destruction. The growth is hour-glass in shape, the smaller part within and the larger mass outside of the vertebral canal, and in many instances it is difficult to determine whether the neoplasm began as a *primary* extradural growth or whether the

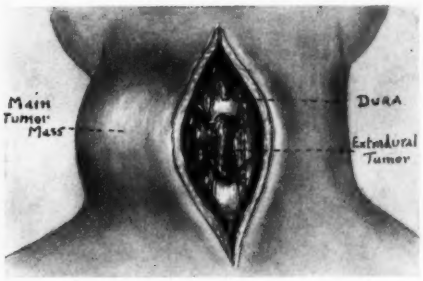


Fig. 20 (left). Case 10 (N. I. A 2755). Showing the tumor at the base of the neck in a case of "cervical neurofibroma."

Fig. 21. Case 10. The relations of the extradural extension into the vertebral canal in the same patient as Figure 20.

extradural part was secondary (Fig. 16). Boerner, Guleke, and Borchardt have called special attention to the dumb-bell shaped tumors which begin outside of the dura within the vertebral canal. In several of their cases, the primary extradural origin of the growth was proved by the fact of outgrowths through two intervertebral foramina.

The clinical course of this form of extradural sarcoma does not differ from that of the first variety excepting that bone changes are more frequent.

b. Tumors which arise from the vertebræ or the intervertebral cartilages and lie entirely within the vertebral canal. In our series there were 7 instances of chondroma derived from an intervertebral disc.

The intervertebral disc chondromata have been recently studied by Dr. Stookey. They are small hard growths, no more than 1 to 1½ centimeters in length, which originate from and are firmly fixed to the anterior wall of the vertebral canal, probably always from an intervertebral disc (Fig. 17). They have been found only in the cervical region, and compress the dura from its ventral aspect, either in the midline or more to one or the other side.

In none of our cases was there any bone changes visible on the X-ray films.

The clinical history may be a short one—less than 6 months, or of 1 to 2 years' duration. In one of our patients the prominent symptom was pain referred to the distribution of one sensory root and at the operation the tumor was found just underneath the affected nerve root (Fig. 18). In all of the other cases, the subjective and objective disturbances pointed to a progressive compression of the cord from its ventral aspect (paræsthesias and dysæsthesias referred to the lower limbs, marked unilateral or bilateral diminution of motor power, sensory diminution which involved especially pain and temperature sensibility and was sometimes of the Brown-Séquard type).

The manometric tests showed that there was a complete subarachnoid block in 2 patients and a partial block in 1, while in the others there was no demonstrable interference in the pathways of the spinal fluid, substantiated in 1 patient by a lipiodol injection. With one exception the fluid removed by lumbar puncture showed neither a change in color, in globulin or protein content, or in the number of cells.

In every patient in whom there are the evidences of a localized and slowly advancing involvement of the spinal cord in the cervical region, in whom X-ray is negative, the spinal fluid normal, and the manometric tests negative or almost negative, the possibility of a ventral intervertebral disc chondroma must be kept in mind.

These ventral chondromata are probably much more common than we have hitherto believed, and vague symptoms referable to

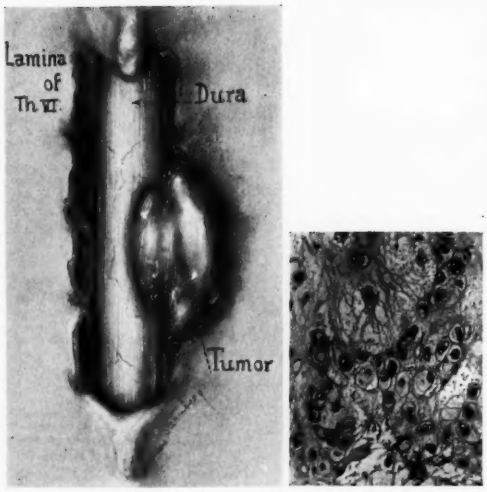


Fig. 22 (left). Case 45 (N. I. A13768). A secondary extradural chondroma exposed at operation (see Fig. 23).

Fig. 23. Case 45. The structure of the tumor—a cellular chondroma (H. and E. stain. × 220).

one or more segments of the cervical cord may in the future be shown to be not so rarely due to a very small cartilaginous outgrowth on the ventral aspect of the dura. The tumors are so small in size and in such a location, that they can be easily missed unless the exploration is made by an experienced neurosurgeon, and they can often be found only after the dura has been incised and the cord rotated and drawn over to one side by traction on the divided slip of the dentate ligament. The small prominence of the dura near the midline can sometimes be felt with the exploring probe after the dura has been opened and can always be seen as soon as the cord has been drawn to one side (Fig. 19).

2. SECONDARY EXTRADURAL TUMORS

The growths that begin outside of the vertebral canal and secondarily extend into it—rarely through intervertebral foramina but more often by bone destruction—are either clinically and histologically malignant or benign. These growths may originate from any of the tissues around or at some distance from the vertebral canal, from the periosteum or from the bone itself, from ligaments, muscles, or their fascial coverings, from spinal sympathetic ganglia, or from nerve sheaths. Growths in the posterior mediastinum or in the thorax (ganglion neuroma, sarcoma, or endothelioma of the pleura, hydatid cysts) may extend into the vertebral canal and compress the spinal cord through the dura. We have seen 5 instances in which progressive cord disturbances were due to the extension into the vertebral canal of a large intrathoracic growth visible on the X-ray films. Two of the patients were operated upon and the nature of the growth verified—1 was a sarcoma and 1 a ganglion neuroma.

The variety of tumor described by Flatau and Sawicki under the name of "cervical neurofibroma" begins from nerve sheaths outside of the vertebral canal and invades both the deep tissues of the neck and the spinal extradural space. In these patients there is a palpable or visible mass at the root of the neck connected with a smaller mass outside of the dura (Figs. 20, 21). The malignant chordoma which originates from the remains of an embryonic entodermal structure, the notochord, usually begins in the body of a vertebra or within an intervertebral disc and secondarily extends into the vertebral canal.

In some instances, secondary malignant growths never invade the vertebral canal and therefore do not make any pressure upon the dura, and in these patients the spinal cord symptoms are due either to interference with the vascular supply of the cord or to the sinking together of the bodies of one or more vertebræ with angulation or compression of the cord segments at the level of the disease. This occurs, however, more often with metastatic than with secondary new-growths.

The tumors that have extended into the vertebral canal from the outside are usually more or less hour-glass or dumb-bell in shape—a larger mass outside being connected with a smaller part of the growth on the outer surface of the dura (Figs. 22 and 23). In some of the secondary sarcomata and in the chordomata, the growth is primarily located in a vertebral body and its extension into the vertebral canal lies in front of the dural sac. More often, however, the extradural part of the tumor lies on the lateral aspect of the

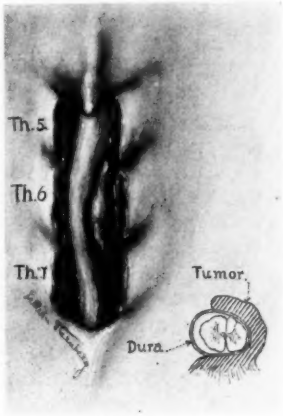


Fig. 24.

Fig. 24. Case 43 (N. I. A 9839). A chordoma exposed at the operation (see Fig. 25).

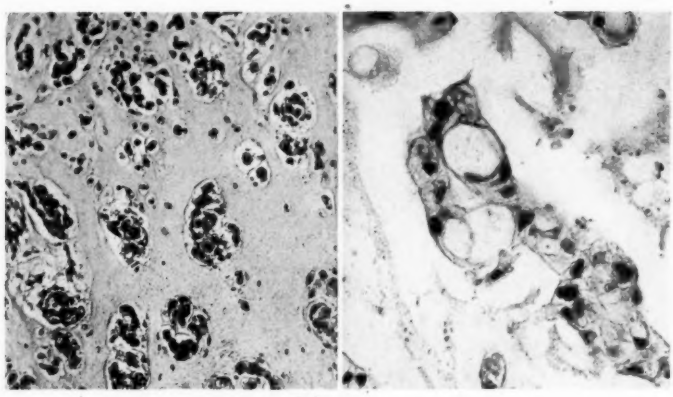


Fig. 25.

Fig. 25. Case 43. The structure of the tumor shown in Figure 24. (A × 160; B × 310).

dural sac and extends both on the posterior and the anterior surfaces of the dura.

Some of these secondary growths are well encapsulated and the mass outside of the vertebral canal lies in a bone cavity with smooth walls, but more often the part within the vertebral canal has a distinct capsule while the primary part of the growth is not well limited by a membrane.

In about 23 per cent of the secondary extradural tumors, the development of spinal cord disturbances is a gradual one and from 1 to 3 years elapse before the cord disturbances are well marked. If it were not for the X-ray findings of more or less marked bone destruction, the differentiation of these from primary extradural and intradural tumors would be difficult. In the remaining 77 per cent of our cases, pain in the back lasting for a shorter or longer period was followed by an advance of spinal cord symptoms more rapid than is seen in intradural growths.

In 17 of the 22 patients with secondary extradural tumors, the spinal symptoms were of less than 1 year's, and in 10 of these of 6 or less months' duration.

If the patient is seen during the period when the tumor is still outside of the vertebral canal, and when he is suffering only from pain in the region of his disease, there may be no bone changes visible on the X-ray films, and the manometric tests of the spinal fluid pressure may be entirely normal. On the other hand, with negative spinal fluid findings, the X-ray evidence of bone destruction may point to the nature of the disease.

The more acute development and the more rapid advance of the signs of spinal cord involvement in most of the secondary sarcomata is easily understood when one takes into account the more active growth of the tumor and its sudden extension into the vertebral canal.

In 85 per cent of the secondary sarcomata the interval between the first symptom and the operation was less than 1 year—on the average between 2 and 7 months.

That a slowly growing tumor such as the chondroma will cause slowly progressive symptoms is to be expected, but it as surprising that the course of the two malignant chordomata in our series was a comparatively slow one. In the 2 cases operated upon by the writer, the interval between the first symptom and the operation was 10 months in 1, and 12 months in the other patient—a duration no shorter than that seen in many benign intradural and extradural growths. One of our patients with the growth in the mid-thoracic region (Figs. 24 and 25) had a slowly advancing spastic paraplegia; in the second case, the growth lay in front of the

Fig. 26. Case 38 (N. I. A 12459). X-ray of a vertebral chondroma.

roots of the cauda equina at the level of the first and second lumbar vertebræ and had caused a marked cauda equina syndrome.

In all of the secondary extradural tumors excepting the 2 chordomata, there was distinct evidence of bone destruction in the X-ray films. The X-ray evidence of the chondromata is characteristic (Fig. 26), but in one case the roentgenogram outlined a growth which had not the typical appearance of a chondroma. The operation exposed a dumb-bell shaped cartilaginous growth (Figs. 22, 23, and 27) which was removed completely in fragments.

The changes seen in the X-ray are more often defects in part of the bodies, arches, or lateral masses of the vertebræ. The defects may not only indicate the amount of bone destruction but very clearly outline the growth (Fig. 28). The disease is usually more extensive than the X-ray changes would indicate.

The alterations in the spinal fluid and in the manometric tests are similar to those found in primary extradural growths.

3. METASTATIC EXTRADURAL TUMORS

Extradural metastases from primary malignant disease of the breast, thyroid, prostate, or gastro-intestinal tract have been studied and reported upon by many writers. They are considered here only because they should be strictly separated from other extradural growths—a fact which has not always been done in papers on extradural tumors.

The metastasis is most often located in or on the lateral aspect of the bodies of the vertebræ and results in more or less extensive bone destruction visible on the X-ray films.

A period of "pain in the back" usually made worse by the slightest movement precedes the appearance of disturbances of cord function. Although a slowly progressive spastic paraplegia may occur, a rapid progress with complete flaccid paraplegia within a few days is more frequent. The cord symptoms may be due to the rapidly increasing pressure on the dura of the new-growth, but in many instances the amount of tumor tissue within the vertebral canal is small and the cord symptoms are due to a sudden myelomalacia from profound disturbance of the blood supply or to the sudden collapse of the bodies of one or more vertebræ.

The spinal metastasis may occur many years after the primary growth has been removed. This happened in one of our patients with a metastatic melanosarcoma, in whom an eye had been removed 14 years before for a primary tumor of the choroid.

Metastatic tumors may cause only severe root symptoms but more often the disturbances of cord function are well marked. Motor disturbances below the level of the lesion may be profound at a period when there is no or only very slight sensory loss. The symptoms of a complete transverse lesion of the cord are, however, very frequent.

Although myeloma is really a part of a multiple disease, as is extradural lymphoma in Hodgkin's disease and metastatic lymphosarcoma, they may be included in the group of metastatic tumors. We have seen one example of each of these tumors. Whenever there is X-ray evidence of bone destruction without a clear history of a primary malignant disease in some other part of the body, the urine should be examined for Bence-Jones albumose in order to exclude myeloma.

THE SURGICAL TREATMENT OF EXTRADURAL TUMORS

The technique of the exposure of primary localized extradural tumors, unless they have

Fig. 27. Case 45 (N. I. 13768). Unusual X-ray appearance of a secondary extradural chondroma.

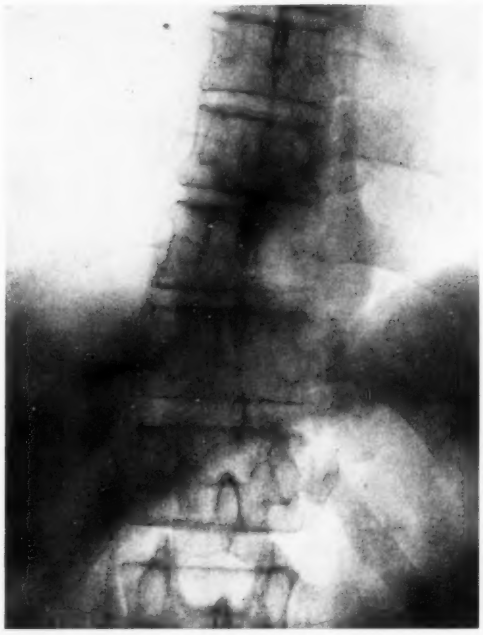


Fig. 28. Case 46 (N. I. B30418). An X-ray of a secondary extradural tumor, which showed the exact size and shape of the growth.

extended beyond the confines of the vertebral canal, does not differ essentially from that for intradural growths, with the exception that the dural sac must often not be opened.

The approach to the ventral vertebral disc chondromata has to be made, in most instances, transdurally. The transdural approach was described by the writer many years ago because of the difficulties in the recognition and the exposure and removal of these small midline growths by the extradural route. The dura is exposed and incised, and the cord is rotated and drawn to one side by traction on a divided slip of the dentate ligament. The bulging dura over the ventrally located growth is then incised and the chondroma which is firmly fixed to the anterior wall of the vertebral canal is removed in layers with a sharp curette. When all of the cartilaginous mass has been removed by this fragmentary excision, the dura will fall into the tumor bed, and suture of the incision in the ventral dura is unnecessary.

During the manipulations, the greatest care must be taken that the cord is not traumatized, and as it is always in plain view, this can be accomplished without special difficulty.

This transdural procedure (Figs. 19, 29, 30) may also be useful for the exposure and removal of other small ventral chondromata not derived from an intervertebral disc, and of small chordomata.

The removal of extradural tumors which surround more or less of the circumference of the dural sac is often unsatisfactory because the ventral part of the growth may be so extensive that only an incomplete fragmentary removal is possible. Not so rarely there is considerable disturbing bleeding from the veins on the posterior surfaces of the bodies of the vertebræ which requires frequent packing with cotton balls soaked with hot saline solution or with adrenalin. In order to obtain a good exposure, the laminæ on one side

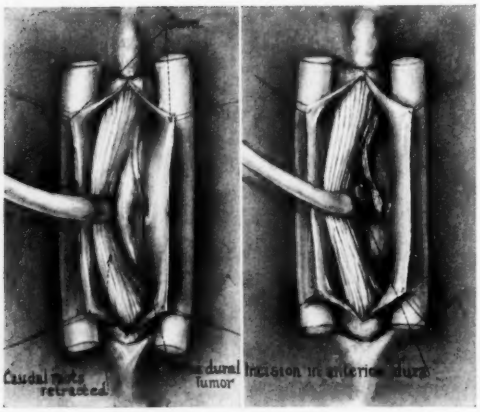


Fig. 29 (left). Case 18 (N. I. 12490). The transdural exposure of a tumor in front of the dural sac. (Compare with Fig. 19).

Fig. 30. Case 18. The appearance after the removal of the growth.

must be removed well out to the transverse processes.

After the part of the growth that lies on the posterior and lateral aspects of the dura has been excised, it may be possible to remove in one piece the extension of the growth on the ventral aspect. More often, however, only an incomplete fragmentary removal is possible. At any time, during the manipulations, the operator may find that the growth extends into the body of a vertebra: that he is actually dealing with a secondary extradural tumor.

If the longitudinal extent of the neoplasm is so great that its limits can not be exposed by the removal of 3 or 4 vertebral arches, the growth is generally surgically irremovable. Little will be accomplished by the excision of the part of the growth that has been exposed, and the operation must be concluded with the hope that the patient will derive benefit from the decompressive effect of the laminectomy and from later X-ray treatment.

The complete removal of the secondary extradural tumors is, in the main, very unsatisfactory. The chondromata can usually be entirely removed together with their capsule, although considerable bone and sometimes pieces of several ribs have to be taken away before the new-growth can be satisfactorily exposed and removed *in toto*. An incision at right angles to the longitudinal one is often necessary.

The histologically malignant but well encapsulated growths, mostly fibrosarcomata can often be completely extirpated from the smooth-walled extravertebral bone cavity in which they lie. At any time during the operation, however, the operator may find that the growth is infiltrating the muscles so that its complete eradication is impossible. In a number of our patients, the tumor removal was complete, for the patients have remained well for many years.

In all cases in which there has been considerable bone destruction visible on the X-rays, the removal of bone should be as sparing as possible commensurate with an adequate exposure of the growth. Sometimes, especially in the cervical region, it is advisable to do only a unilateral laminectomy, as recommended by Dr. A. S. Taylor.

Prognosis and Results

The impression is widespread that the prognosis in extradural tumors is a very poor one, that few patients improve after surgical interference, and that only exceptionally is a radical cure effected. This impression, voiced in many textbooks, is an erroneous one and

TABLE III.—RESULTS IN THIRTY-FOUR CASES

	Primary	Secondary	Total
Died within 1 year	0	5	5
Died within 2 years	2	1	3
Died within 4 years	0	1	1
Living 1–2 years	2	2	4
Living more than 2 years	3	4	7
Living more than 4 years	6	3	9
Unknown	2	3	5
			34

If we exclude 1 patient who died from an accident about 2½ years after the operation, 19 patients are still living and their present condition has been ascertained. Of these there are well or almost well, 14; unable to work, 3; recurrences, 2; a total of 19 cases.

Of the patients with benign tumors, there are 3 alive 1 to 2 years, 12 alive more than 2 years after the operation.

Of the sarcomata there are of those who died within 1 year, 3; within 2 years, 2; within 4 years, 1. There are 2 living 1 to 2 years; 4 living 3 to 4 years or more. In 4 the outcome is unknown, and in 2 there was a recurrence.

has been due to the inclusion in one group of not only the primary but also the secondary and often the metastatic growths.

Spinal metastases are, from their nature, practically always irremovable, and as in all metastatic growths should only exceptionally be attacked surgically. If metastatic growths are excluded, almost 50 per cent of extradural tumors are benign in nature and technically removable, and therefore in at least one-half of patients with extradural growths, complete eradication of the disease is possible. In addition, some of the primary and secondary encapsulated sarcomata can be completely removed.

The end-results in the 46 patients of our series can be seen in Tables IV and V.

The dangers of the operation in patients with extradural neoplasms are not much greater than that of laminectomy for intradural tumors or for other diseases. In 3 of our 46 patients, or 7 per cent, death was due directly to the operative procedure. One patient, operated upon many years ago, a child of 3 years, with a secondary ganglion neuroma, died from shock after the removal of a large encapsulated growth. The second fatality was in a case of ventral chondroma. The patient's wound was healed and she had improved very much 2 weeks after the operation when she died suddenly from a pulmonary embolism. The third patient unfortunately succumbed to a wound infection 2 months after the operation.

Table III shows the results in 34 patients, the 3 operative fatalities and 9 cases in which operation was done less than a year ago having been excluded.

Summary

1. Exclusive of intramedullary tumors and of metastatic extradural and intradural growths, about one-fourth of all spinal tumors are extradural.

2. The meningeal and perineurial fibroblastomata constitute 17 per cent of the extradural and 82 per cent of the intradural tumors; the sarcomata and chondromata, 61 per cent of extradural and 6 per cent of intradural growths.

3. In general, the clinical course of extradural tumors is more rapid, sudden exacerbations of symptoms not unusual, exaggeration of symptoms and signs after withdrawal of fluid by lumbar puncture very frequent. The early symptoms are often vague in character: root pain infrequent; contralateral motor disturbances and contralateral paræsthesias and the reverse Brown-Séquard syndrome often observed. The increase of globulin or total protein is rarely, if ever, as marked as in intradural tumors, and in many of the vertebral disc chondromata there is no evidence of subarachnoid block by the manometric tests.

4. Extradural tumors should be divided into primary, secondary, and metastatic. Exclusive of the metastatic growths, 52 per cent were primary and 48 per cent were secondary.

5. Many of the primary extradural growths are benign and encapsulated and completely removable. The meningeal and perineurial fibroblastoma, the fibroma, angioma, and chondroma are usually single. The primary extradural chondroma occurs in two forms: In the one, the growth lies in the extradural space on the ventral or dorsal aspect of the dural sac; in the other, the growth is derived from and firmly fixed to an intervertebral disc.

The primary extradural sarcomata occur in two forms. Either the growths are derived from the dura and have no tendency to become adherent to or involve the walls of the vertebral canal, or they begin within the canal and erode the bone and grow outwards, forming hour-glass or dumb-bell-shaped tumors.

6. The secondary tumors grow into the vertebral canal either through intervertebral foramina or by bone erosion. They arise from the vertebræ or paravertebral soft tissues and may be extensions of growths in the thorax or deep tissues of the neck or back. The spinal cord symptoms are due either to the pressure of the extradural part of the growth or to interference with the blood supply of part of the cord, and the symptoms are, excepting in the chondromata, more acute in their onset and more rapidly progressive. The chordomata are true secondary extradural tumors, although their clinical course was as slow as that of many benign extradural and intradural tumors.

TABLE IV.—PRIMARY TUMORS

Case No.	Age in years	Duration of cord and root symptoms, in months	Motor symptoms	Sensory symptoms	Date and nature of operation	Nature of tumor	Vertebral level	Result	Present condition
1 N.I. 4955	18	36	Spastic paraplegia	Slight	February 14, 1914, removal of encapsulated tumor	Fibroma	T. IX–XI	Well	13½ years.
2 N.I. 14317	37	7	Spastic paraplegia	Distinct	January 18, 1918, removal of encapsulated tumor	Sarcoma	T. IX–XI	Little improvement	Died after 14 months.
3 N.I. 20807	59	42	Tetraplegia	Very marked	October 2, 1920, removal of encapsulated tumor	Perineurial fibroblastoma	C. III–VI	Great improvement	6 years, 10 months.
4 M.S.H. 211312	57	7	Spastic paraplegia	Well marked	July 12, 1921, removal of encapsulated tumor	Meningeal fibroblastoma	T. IV	Great improvement	Unknown.
5 M.H.	36	30	Spastic paraplegia	Well marked	November 26, 1921, incomplete fragmentary removal	Sarcoma	T. VII–L.V	No improvement	Died 18 months after operation.
6 M.S.H. 208316	57	12	Spastic paraplegia	Well marked	May 3, 1922, complete transdural removal	Chondroma of vertebral disc	C. VI	Some improvement	Unable to work. Living 5 years after operation.
7 M.S.H. 220312	64	18	Spastic paraplegia	Slight	June 20, 1922, removal of encapsulated tumor	Angioma	T. II–V	Well	5 years.
8 N.I. 24348	9	2	Spastic paraplegia	Marked	October 9, 1922, complete fragmentary removal	Giant-cell sarcoma	T. IV–VI	Great improvement	4½ years. Well.
9 N.I. 24766	44	5	Moderate spasticity	Tactile, normal; pain and temperature, moderate	January 22, 1923, fragmentary removal	Chondroma of vertebral disc	C. VII	Little improvement	4 years, 6 months; unable to work.
10 N.I. 26954	54	24	Normal	Normal, root pain	May 29, 1924, fragmentary removal	Chondroma of vertebral disc	C. VII	Some improvement	Died from accident 2 years, 4 months after operation.
11 N.I. 26932 27444	56	1	Spastic paraplegia	Marked	May 31, 1924, removal	Sarcoma	T. III–VI	Improved	Present condition unknown.
12 N.I. 27572	30	12	Spastic paraplegia	Moderate	October 22, 1924, removal of encapsulated tumors	Neurofibroma v. Recklinghausen	C. IV–VI	Little improvement	3 years.
13 N.I. A4933	38	46	Spastic paraplegia	Marked	November 26, 1924, complete removal	Perineurial fibroblastoma	T. I and II	Great improvement	Still well.
14 M.S.H. 261881	28	1½	Some spasticity; marked weakness	Slight	July 17, 1925, fragmentary removal July 23, 1927, removal of recurrence	Meningeal fibroblastoma	T. V–VI	Well	Well for 1¾ years, then recurrence. Well since last operation.
15 N.I. A9905	26	38	Spastic paraplegia	Marked	June 7, 1926, removal of two encapsulated tumors	Perineurial fibroblastoma	T. I and II	No improvement	Died 2 months after operation.
16 N.I. A11064	38	24	Marked weakness	Slight	August 3, 1926, removal of encapsulated tumor	Neurofibroma v. Recklinghausen	C. VII and T. I	Well	Still well.
17 N.I. A11962	56	5	Slight weakness	Moderate	September 16, 1926, fragmentary removal	Meningeal fibroblastoma	T. IX–X	Great improvement	Well.
18 N.I. A12490	46	6	Flaccid paraplegia	Slight	September 25, 1926, complete removal	Chondroma	L. III–IV	Great improvement	Still well.
19 N.I. A12732	49	34	Slight spastic paraplegia	Distinct	October 28, 1926, fragmentary transdural removal	Chondroma of vertebral disc	C. IV–V	Some improvement	
20 N.I. A13144	29	10	Spastic paraplegia	Marked	November 8, 1926, removal of encapsulated tumor	Perineurial fibroblastoma	T. IV–VI	Well	10 months.
21 N.I. A12822	68	11	Weakness left upper and lower limbs—Babinski	Tactile; pain and temperature very slight	March 22, 1927, fragmentary transdural removal	Chondroma of vertebral disc	C. III–IV		
22 M.S.H. 279954	33	3	Moderate spastic paraplegia	Slight	June 7, 1927, removal of encapsulated tumor	Lipoma	T. VIII–IX	Great improvement	
23 M.S.H. 281013	47	2	Moderate spastic paraplegia	Brown-Séquard	July 1, 1927, complete removal	Chondroma of vertebral disc	C. VI–VII	Marked improvement	Died 2 weeks after operation of pulmonary embolism.
24 N.I. B5089	34	21	Spastic paraplegia	Marked	August 11, 1927 removal of encapsulated tumor	Capillary angioma	T. V–VI		

TABLE V.—SECONDARY TUMORS

TABLE V.—SECONDARY TUMORS

Case No.	Age in years	Duration of cord and root symptoms, in months	Motor symptoms	Sensory symptoms	Date and nature of operation	Nature of tumor	Level	Result	Present condition
25 N.I. 4819	12	12	Tetraplegia	Tactile, shifting. Tactile and pain marked	May 31, 1912, removal of encapsulated tumor; 1921, removal of recurrence (Dr. Rixford)	Fibrosarcoma	C.VI–VIII	Great improvement	Recurrence after 9 years. Second operation (Dr. Rixford)—again improved. Living after 15 years.
26 N.I. 5354	55	12	Spastic paraplegia	Complete loss to level	January 20, 1914. removal of encapsulated cheesy mass	Tuberculoma	T. V–VI	No improvement	Died 2 years later from pulmonary tuberculosis.
27 N.I. 10627	3	13	Spastic paraplegia	Marked	July 1, 1916, removal of encapsulated tumor	Ganglion neuroma; extension from thoracic growth	C. VII–T.V.	Death	28 hours after operation—shock.
28	56	9	Spastic paraplegia	Marked	August 16, 1920, fragmentary removal	Round-cell sarcoma	T. V–VI	Great improvement	Well 7 years after operation.
29 N.I. 21152	52	6	Spastic paraplegia	Marked	November 23, 1920, fragmentary incomplete removal	Sarcoma; extension from thoracic growth	T. VI–VIII	No improvement	Unknown. Probably died within year of operation.
30 M.S.H. 209297	16	24	Moderate spastic paraplegia	Marked	April 11, 1921, fragmentary removal	Fibrosarcoma	T. V	Great improvement	Well 6½ years after operation.
31 N.I. 23352	54	6	Spastic paraplegia	Marked	February 8, 1922, incomplete fragmentary removal	Sarcoma	T. III–VI	No improvement	Died within 1 year.
32 N.I. 10499	49	4	Tetraplegia	Tactile, normal. Pain and temperature slight	March 22, 1923, incomplete fragmentary removal	Sarcoma	C. VI–VII	Marked improvement	Died from recurrence and cerebral metastasis about 4 years later.
33 N.I. 25038	26	6	Spastic paraplegia	Marked	March 27, 1923, removal of encapsulated tumor	Sarcoma	T. VII–VIII	Marked improvement	4½ years after operation, practically well and at work.
34 N.I. A2755	3	7	Flaccid paraplegia	Slight	January 28, 1923, removal of extradural tumor; later incomplete fragmentary removal of tumor in neck	Cervical neurofibroma	C. III–VI	Little improvement	Still living 3½ years postoperative.
35 N.I. 26431	51	7	Spastic paraplegia	Marked	February 4, 1924, incomplete fragmentary removal	Sarcoma	T. V–VII	Slight improvement	Present condition unknown.
36 N.I. 26480	57	4	Spastic paraplegia	Marked	February 14, 1924, incomplete fragmentary removal	Sarcoma	T. V–IX	Little improvement	Died 1 year later.
37 M.S.H. 239678	23	4	Slightly spastic	Slight	February 29, 1924, fragmentary removal	Chondroma	T. IX–XII	Well	3½ years after operation.
38 N.I. A12459	29	30	Marked weakness	Slight	September 17, 1924, partial excision. Further excisions Oct., 1926, and April, 1927	Chondroma	T. VII–XII	Improved	3 years after operation, considerable improvement.
39 N.I. 25906	16	2	Slight	Slight	Oct. 17, 1924, tumor not removed	Sarcoma	L. V–S. I–II	Slight improvement	Date of death unknown.
40 N.I. 27896	32	3	Spastic paraplegia	Marked	January 15, 1925, incomplete fragmentary removal	Sarcoma secondary to tumor in chest	T. II–VI	Not improved	1 year and 8 months—still living.
41 N.I. A2224	29	36	None	Slight	July 27, 1925, fragmentary incomplete removal; second operation in 1927	Chondroma	T. XII–L.I–II	Considerable improvement	2 years, 2 months—unable to work; confined to bed and chair.
42 N.I. A8846	8	1¼	Moderate spastic paraplegia	Slight	April 27, 1926, May 21, 1926, incomplete fragmentary removal	Fibrosarcoma	C. IV–V	Great improvement	Well 15 months; now recurrence in neck.
43 N.I. A9839	57	12	Spastic paraplegia	Marked	May 24, 1926, incomplete fragmentary removal; April 9, 1927, second operation	Chordoma	T. IV–VI	No improvement	Died 10 months later.
44	64	11	Flaccid paralysis	Fairly marked	June 24, 1926, incomplete fragmentary transdural removal	Chordoma	L. I, II	No improvement	Died 6 months after operation.
45 N.I. A13768	63	36	Marked spastic paraplegia	Marked	December 27, 1926, complete removal	Chondroma	T. VII–VIII	Well	8 months.
46 N.I. B30418	56	6	Moderate spastic paraplegia	Tactile, normal. Pain and temperature, moderate	April 30, 1927, fragmentary removal	Sarcoma (Gaucher) Final report: Chordoma	T. IX–XII	Great improvement	5 months—still suffering from root pain.

7. The spinal cord symptoms of metastatic extradural growths are usually rapidly progressive and bone destruction visible on the X-rays is very frequent. The symptoms are often due to interference with the blood supply of part of the cord or to the collapse of the bodies of one or more vertebræ.

8. The clinical course of the various types of extradural tumors was described and their gross and histological structure illustrated.

9. Most of the primary and many of the secondary extradural tumors can be completely removed. Some features of the surgical technique were discussed. The cases in which transdural operation is preferable were described and the technique of transdural removal of ventral extradural growths was illustrated. The complete removal of metastatic and of some primary and many secondary extradural tumors is impossible.

10. More than one-third of patients with primary or secondary extradural tumors can be greatly improved or permanently cured. The proportion is larger in the primary than in the secondary, and in benign than in malignant tumors.

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THE INFLUENCE OF FIBROIDS ON PREGNANCY AND LABOR[1]

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FIBROIDS produce a relative degree of sterility, either by impairing fertility or by favoring the early termination of conception by the production of abortion. Conversely, it may be stated, that the barren uterus is more prone to the development of fibroids than the uterus which is alternately going through periods of hypertrophy and involution. Nearly one-third of the patients who are the subjects of this form of neoplasm remain sterile. The most important clinical fact relative to sterility and fertility is not that the uterus contains a fibroid or fibroids —but what is their location and size? The probable explanations of why fibroids affect fertility and predispose to abortion, are:

a. The disturbance in the normal menstrual cycle due to circulatory changes which affect the endometrial surfaces contiguous to the fibroid. This is particularly evident in submucous and interstitial growths which are of sufficient size or in such a location as to distort the contour of the uterine cavity and produce atrophy or hypertrophy of the lining mucosa.

b. In addition to this instability in embedding the ovum, there is further added an increased muscular activity of the uterine contractions, which are constant and tend to evolve the tumor in the direction of least resistance, inward or outward, depending on its relation to the musculature. This state of intermittent contraction is, therefore, unfavorable for the growing ovum. This is illustrated by the fact that in the author's series, 21 per cent of the pregnancies occurring in fibroid uteri have terminated in abortion or premature labor. This is a slightly lower incidence than that reported by Pierson of 24 per cent, but higher than that of Pinard with 15 per cent. According to Scipiades, pregnancy with myoma results in abortion or premature labor in fully 50 per cent of the cases.

Not only do fibroids influence the growth and the development of the pregnant uterus, but pregnancy has a like effect upon the fibroid, as in pregnancy the uterus is increased in size—this is not only due to the increasing bulk of the developing ovum, but also to the more abundant blood supply and an actual hypertrophy of the uterine muscle. Likewise, fibroids which have their nutrition increased will grow more rapidly and take part in the general succulence and hypertrophy of the contiguous structures. *It is, however, their location which will determine their effect upon the particular pregnancy:* remembering that all tumors in the uterine wall are evolved in the direction of least resistance, one can readily see how a subperitoneal tumor with a sessile base which may develop near the fundus may, under the influence of pregnancy and its increased blood supply, rapidly enlarge and fill the greater part of the abdomen, at times reaching the ensiform, or by uterine contraction be extruded beneath the peritoneum, become pedunculate, twisted, and necrose—and yet have little effect upon the pregnancy which is growing within the uterus. On the other hand, a tumor in such a position may by its weight displace the uterus backward and incarcerate it in the pelvis in such a way as to produce circulatory disturbances blocking the venous return, producing nerve pressure, and œdema—the latter not only in the tumor but in the covering and contiguous peritoneum with consequent adhesions. Such a development resulting from incarceration must necessarily either end in abortion or in the anomalous development of the ovum in the anterior uterine wall.

Should this same tumor be situated near the fundus and have an interstitial location, its influence on the development of pregnancy would be entirely different; for while it might distort the uterine cavity, unless it became submucous, it would have no effect on the endometrial lining—hence, we see many pregnancies complicated by interstitial tumors which go to term without producing any abnormal symptoms. This, however, is not true in submucous growths which are naturally

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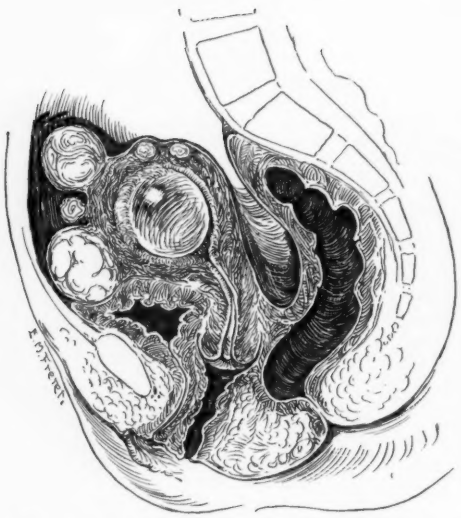

Fig. 1. The type of fibroid which does not interfere with development of pregnancy.

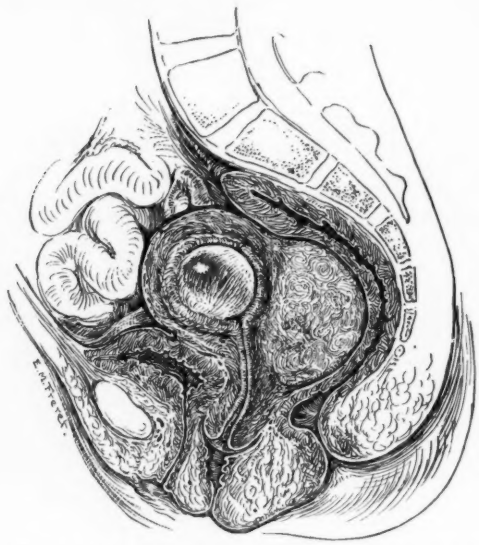

Fig. 2. Incarcerated interstitial growth raised out of the pelvis by the developing uterus.

more and more extruded into the uterine cavity. This necessarily produces a pressure atrophy in the overlying endometrium and a hypertrophy largely the result of the œdema in the contiguous uterine lining. Such a mucosa offers a poor surface for embedding—and when embedding does occur on the atrophic surface, placenta acreta is not unlikely to follow. Furthermore, the location of the tumor as it grows dislocates the fetus and determines its position within the uterus. Oblique positions of the fetus or breech presentations in the mid and final trimesters are not infrequent; while the occurrence of placenta prævia is relatively more common; low implantation is found as a complication in about 6 per cent of pregnancies occurring in myomatous uteri. This is probably due to the difficulty which the ovum has in finding a suitable place to embed because of the endometrial œdema associated with these growths.

Tumors in the lower segment of the uterus or cervix, of any considerable size, have a clinical significance, for they may not only interfere with conception by changing the position of the external os and its relation to the seminal pool, or in changing the character of the uterine secretion, but may later become an important factor in the conduct and management of labor. Fortunately, however, after impregnation has taken place they do not in any way affect the development of the ovum, except as the fetus grows they tend to produce malpositions owing to the fact that the head cannot fill the lower segment; but at labor they present a mechanical factor which may block delivery or interfere with the lochial drainage in the puerperium. Subperitoneal tumors produce little effect on the presentation or posture of the child, unless they are located in the pelvis, and many times the labor associated with tumors located in the upper segment is easy and uncomplicated—but because of their rapid growth they may cause extreme abdominal enlargement and pressure embarrassment to the heart and lungs, and interfere with contiguous visceral functions.

All observers agree that abnormal positions are relatively common complications of pregnancy. When the pregnancy is complicated by fibroids these malpresentations not only predispose to early rupture of the membranes which is often followed by premature labor

Fig. 3. Incarcerated myoma of lower segment, posterior wall, making intravaginal delivery impossible.

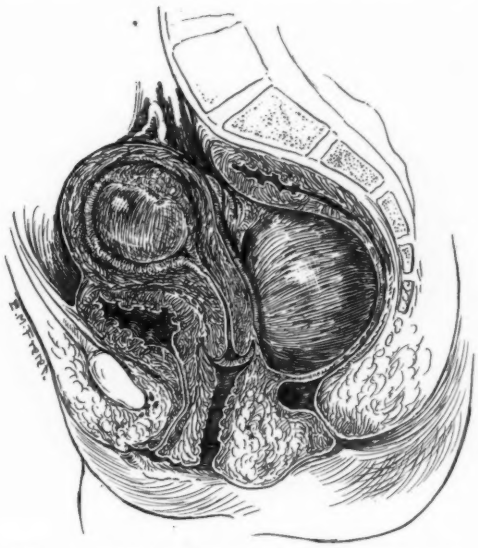

Fig. 4. Twisted pedunculated subserous tumor incarcerated; cæsarean followed by myomectomy.

or dry labor, but cause uterine inertia and mechanical dystocia. Lynch in a review of this subject by a study of his material at the University of California, found an incidence of cephalic presentation in 59 per cent; breech in 22 per cent; transverse in 18 per cent. This means that labor must be more complicated, as even a cursory examination of Pierson's excellent table will show. He reviewed the histories of 30,000 labors at the Sloan Hospital for Women, and from these he collected 250 cases in which the fibroid tumor was of such a size as to have clinical consideration in the course of pregnancy or labor, and then compared the obstetric accidents and abnormalities occurring in this series with those occurring in 8,300 consecutive unselected cases.

These statistics are in line with the personal experience of the writer and should direct the attention of obstetricians to the necessity of correcting the statement so commonly made in textbooks, i.e., "although the association of fibromyomata and pregnancy is a relatively frequent one, disturbance by them of the normal course of pregnancy and labor is unusual." Certainly we cannot subscribe to such a statement, for any condition which increases the average incidence of abortion or dry labor, operative interference, postpartum hæmorrhage and fetal and maternal mortality from 3 to 6 times the average, deserves a more careful clinical consideration. Furthermore, while fibroids have these unfortunate effects on pregnancy, pregnancy, likewise, has an important influence on fibroids, for a relatively large percentage undergo some degeneration resulting from circulatory stasis.

Sneed states that 13 per cent of fibroids undergo some form of degeneration during pregnancy. The increased blood supply which is concomitant produces such circulatory changes in the tumor as hypertrophy, hyperplasia and increased vascularity; therefore, all fibroids grow more rapidly under the influence of pregnancy. These tumors become more prominent, or flatten out, or they may alter their shape and position due to change in location and axis.

During gestation and the puerperium the tumor may undergo necrobiosis or red degeneration, œdema or necrosis. Red degeneration is a partial death of the tissues within the tumor, with hæmorrhage into the growth (a

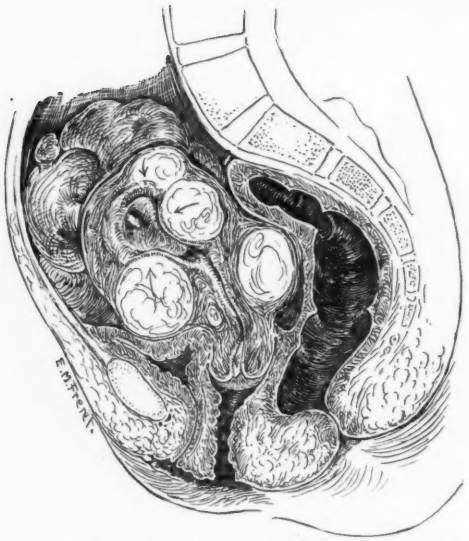

Fig. 5. Interstitial and submucous growths causing dystocia inertia during first stage and postpartum hæmorrhage in the third.

Fig. 6. Necrotic fibroid causing fatal sepsis. Fetus delivered by forceps traumatizing growth in passage.

partial aseptic necrosis), yet is usually surrounded with sufficient healthy tissue to recover. In this form of degenerative change the red blood cells are hæmolized and the blood pigments unite with necrotic cells. This complication is more common in interstitial growths, since in these, there is lessening of the blood supply, owing to the intermittent contractions of the uterine muscle, which is constantly attempting to evolve the growth in the direction of least resistance. These contractions more or less free the tumor from its surrounding capsule and leave it in a space in which the blood supply may be inadequate.

Red degeneration occurring during pregnancy presents a typical symptom complex. There is sudden pain referred to the region of the tumor. This is usually followed by the appearance of a bloody vaginal discharge, small in amount, bright in color; an elevation in pulse and temperature, a moderate leucocytosis and a drop in the sedimentation time. Abdominal palpation shows a sudden increase in the tension and tenderness over the tumor mass—the tumor itself increases in size.

Red degeneration is most common during pregnancy, especially in the mid trimester; while œdema and necrosis with or without infection of the tumor are conditions which may be looked for during the puerperium. A degenerated subserous fibroid may be sterile, when it will cause few if any symptoms, or it may become adherent to the intestine, be infected and suppurate and simulate the picture of an "acute abdomen" with its abdominal pain, tension, distention, temperature, nausea, vomiting, and leucocytosis.

The submucous or interstitial tumor may be partly or completely extruded into the cavity of the uterus during the puerperium. As a result of contraction and retraction this may lead to infection of the necrotic mass and produce a puerperal infection with foul lochia and endanger the woman's life from sepsis and continued hæmorrhage. Myomata may make pregnancy pathologic by their influence on the symptoms of gestation; for instance, pain is often constant, uterine contractions are not only increased but are made more painful or, because of the situation of the myoma, the uterus may be displaced and packed into the pelvis and occasion a train of pressure symptoms in the bladder, the rectum, and in the pelvic veins and nerves extending down the

thighs and legs. Furthermore, anomalous bleeding is not exceptional, and when the tumor is large and rapidly growing, symptoms of abdominal distention with digestive, cardiac, and pulmonary embarrassment may obtain.

Fibroids may have a marked influence on labor as there is usually a preponderance of abnormal presentations in pregnancy complicated by these growths. This we have seen predisposes to early rupture of the membranes, uterine inertia, prolonged labor, a high operative incidence, postpartum hæmorrhage, and an increased mortality to both mother and child. But this, again, is dependent, not on the presence of the tumor but upon its location, size, or the number of tumors, and their relation to the contracting or dilating zones in the uterus.

Subserous tumors usually do not interfere with parturition unless they encroach upon the lower segment or are subvesical, intraligamentous, or become twisted, adherent, or impacted in the cul-de-sac. Impacted myomata are often so placed that uterine contractions cannot lift the tumor out of the pelvis. On the other hand, tumors which during pregnancy seem impossible, may be lifted out of the pelvis by uterine contractions and allow spontaneous labor to take place.

Growths that are firmly impacted in the pelvis, displacing, distorting, blocking the cervical os, may prevent any form of infravaginal delivery, and, when the construction is unrecognized, cause rupture of the uterus. Infravaginal delivery through a blocked pelvis always has had a high operative mortality for the mother. Pierson reports 30 pelvic tumors in 191 cases in which the fibroid was of sufficient size and in locations to cause anxiety to the attendant. Cragin and Ryder found 11 in 98, while we had 6 in 60. The respective operative incidence in these three series was 81, 73, and 66 per cent.

Multiple myomata in the body of the uterus have a direct influence on the character and force of the uterine contractions. We have observed that women in the fourth decade of life who are subject to multiple uterine myomata, frequently exhibit instances of primary inertia. This uterine inertia not only manifests itself during the first and second stages of labor, but continues into the third and becomes an important factor in the causation of postpartum hæmorrhage. In Pierson's series, hæmorrhage occurred in 33 per cent; in ours, in 25 per cent.

Fig. 7. Cervical myoma preceding the head. Tumor delivered by vaginal myomectomy followed by spontaneous birth.

The first stage of labor is usually delayed and prolonged, the contractions are irregular and ineffective though they are often more painful, for much of the muscle area has been replaced by tumor masses, and if the tumor is in the lower segment of the uterus and prevents a normal presentation with its ball-valve action, early rupture of the membranes is the rule and will be found recorded in from 45 to 60 per cent of the cases. This, of course, is an added factor in retarding the first stage. Likewise, with the high incidence of malpositions and early rupture of the membranes, it naturally follows that prolapse of the cord is more common, owing to the fact that the presenting part fails to fill the dilating lower segment. However, should the presenting part come into the pelvis and the tumor be displaced, the second stage is not necessarily prolonged though it may be more painful. It is in the third stage in which fibroids often

Fig. 8. Immense impacted tumor necessitating section and hysterectomy.

manifest their most serious influence. This stage is abnormal in about 30 per cent of the cases, and this abnormality is manifested first, by interference with the placental separation and expulsion; second, by postpartum hæmorrhage; third, by the occurrence of retained or adherent placentæ and faulty drainage. All of these complications must be thought of in dealing with this phase of labor.

As a matter of clinical fact, while fibroids may produce all of the aforementioned complications, it is interesting to note that in large series of deliveries relatively few actually require radical surgical intervention. In the Glasgow Maternity in 13,000 deliveries, only 4 required abdominal section for dystocia which was directly attributable to the presence of fibroid. At the Clinic Baudelocque in Paris, out of 14,000 deliveries, myomata of sufficient size to be considered of significance in the conduct of labor, were found in 84, yet 66 of the cases went to term and had spontaneous deliveries. In Cragin's study of 20,000 cases at the Sloan Maternity, there were 84 which were complicated by noticeable myomata, but only 11 had pelvic tumors, 9 of which required abdominal section or destructive operations for delivery. In Pierson's recent review of 30,000 cases, there were 191 patients in whom the fibroids were of sufficient clinical importance to require painstaking observation. In this number there were 30 pelvic fibroids, 22 of which required some form of operative intervention to terminate the labor. In my personal series of 7,000 cases, there were 60 in which the position and size of the fibroid gave us anxiety during pregnancy and labor, yet there were but 6 tumors which required removal during pregnancy; and 4 which demanded section during labor to accomplish delivery. One pedunculate tumor of cervical origin was pushed out of the vulva in advance of the presenting part, enucleated by vaginal myomectomy; and spontaneous delivery followed. Hence, it will be seen that nature and retraction of the lower segment of the uterus

during labor are capable in most instances of taking care of the mechanical obstruction.

From the foregoing discussion it is shown that there is an incompatibility between pregnancy and fibroids. This is demonstrated by (1) the frequency of sterility; (2) the tendency to abortion and premature labor; (3) the stormy experience which some of these patients have in pregnancy and labor; and (4) the degenerative changes which occur in these tumors in the puerperium.

TREATMENT

The question of the management of fibroid tumors in pregnancy resolves itself into determining (1) whether the life of the patient is endangered by allowing the growth to remain, and (2) what effect its removal will have upon the continuation of pregnancy. Our experience shows that women with myomata of the uterus go through pregnancy and often repeated pregnancies with but little difficulty. Tumors that are apparently impacted in the pelvis are frequently lifted out spontaneously either in the course of pregnancy or labor. Therefore, the necessity of emptying the uterus by therapeutic abortion when myomata complicate pregnancy very rarely occurs; and hysterectomy with the non-viable child *in situ* is one of the rarest necessities in surgery. In the interest of the child, interference should be delayed as long as possible. The policy should be intelligent aseptic expectancy, but we should always be ready to act. Therapeutic abortion has no place and is unsafe and unnecessary, for not infrequently this is the only pregnancy which this woman may have; and interference may damage the tumor tissues to such a degree that convalescence may be protracted and disturbed, for the drainage in a fibroid uterus is poor and perforation of the tumor capsule may be the origin of infection. On the other hand, spontaneous abortion apparently seems to obviate these dangers. The majority of cases will not require surgical interference, unless the tumor by its location or degeneration seriously disturbs, changes, or endangers the health of the patient.

It has been our practice to delay any operation until after the viability of the child and

Fig. 9. Impacted tumor blocking delivery. Treated by section and hysterectomy.

try to prevent abortion by instruction as to marital relations, rest at the expected menstrual periods, with the daily employment of the knee-chest posture, for by the use of this posture, the tumor mass and uterus does not become impacted in the pelvis, and the pelvic engorgement is relieved.

When the tumor is found in the pelvis in the early months of pregnancy, we try to displace it with the patient in the knee-chest posture. When this fails, we continue the use of the knee-chest posture preceded by a minute or two of the "mule kick" three times a day and wait to see what nature will do. The tumor is frequently carried up and out of the pelvis by the growth of the uterus, or during the first stage of labor by the retraction of the lower segment. Only when the tumor has become (1) incarcerated and (2) when a pedunculated tumor becomes twisted or a (3) subserous growth enlarges so rapidly that it embarrasses the heart, or respiration, or the development of the pregnancy, is any operation called for during the progress of the gestation.

Several experiences with operation for red degeneration has taught us that it is safer to allow the acute symptoms to subside and the

TABLE I.—COMPARISON OF INCIDENCE OF CERTAIN OBSTETRIC ABNORMALITIES IN CASES WITH FIBROMYOMATA, WITH EIGHT THOUSAND THREE HUNDRED SEVENTEEN CASES (PIERSON)

	Fibromyomata per cent	Unselected cases per cent
Abortion, premature labor	24	14.0
Dry labor	44.5	7.5
Uterine inertia	34.6	1.0
Prolonged labor	16.8	7.5
Medium forceps	16.8	5.0
High forceps	2.9	0.6
Breech delivery, Mauriceau	18.8	6.0
Internal podalic version	8.9	2.0
Hæmorrhage	33.6	4.0
Fetal mortality after 3 months	32.1	6.0
Maternal mortality	3.6	0.9

pregnancy to progress than to attempt myomectomy for this complication—for clinical and pathological study of this form of circulatory necrosis shows that it is usually checked before tumor destruction has progressed to any marked degree, and seldom has a serious effect upon the pregnancy.

CONDUCT OF LABOR

Manipulation through the vagina is of little avail when the tumor is incarcerated and blocks the birth passage. Attempts to displace it manually may result in injury to the mother, to the child, and to the tumor. It is far better to use the knee-chest position and wait for the retraction of the lower segment. If this does not lift the tumor out, the delivery should be by section followed by enucleation or hysterectomy, as the individual peculiarities of the case require.

Tumors of the cervix or subvesical or intraligamentary growths can rarely be pushed out of the pelvis and because of their position cannot be expected to retract; hence, suprapubic delivery becomes a necessity. Whether we do a myomectomy or a hysterectomy will depend entirely upon the situation, the size of the tumor, and the number of fibroids in the uterus. The convalescence from hysterectomy is much smoother than that following cæsarean with myomectomy, and of late, we have leaned toward the former.

THE MANAGEMENT OF THE PUERPERIUM

All fibroids undergo some degree of œdema immediately after delivery, many of these,

TABLE II.—COMPARATIVE INCIDENCE IN MALPOSITION

Fibroids:	Cephalic	Breech	Transverse
Lynch	59	22	18
Olshausen	53	24	19
Incidence in 5000 unselected cases without fibroids—L. I. Col. Hosp.	95	3	2

particularly intramural growths, diminish in size and disappear during involution; but injury to the tumor during labor may be followed by necrosis or infection and may create an emergency which will require early radical operation during the puerperium. Involution is more tardy—submucous tumors are likely to be extruded in the uterine cavity and become pedunculate, hence, uterine hæmorrhage is not uncommon. Subserous tumors may become twisted and necrose and require abdominal operation; while submucous tumors usually become pedunculate and are more or less completely extruded through the cervix by uterine contraction, when they may be removed by vaginal myomectomy.

In general, it may be stated that surgery in the puerperium is only indicated in the pedunculate, subserous, and intra-uterine polypoid growths; and that radium and X-ray have no place in the management of the hæmorrhages from these tumors during the puerperium.

DISCUSSION

DR. REUBEN PETERSON, ANN ARBOR, MICHIGAN: Fortunately or unfortunately, according to the point of view, the obstetrician and gynecologist is not called upon very frequently to decide between cæsarean section and hysterectomy in the interests of either the full term fetus or the mother. This is for the reason that degenerative changes in the fetus are manifest early. For some years I have been sending to Professor Huber of the University of Michigan all early embryos. In not a few instances in which the fibroid uterus demanded removal and the woman was a month or two pregnant, I had hoped to add a perfect early fetus to his collection of embryos. Almost without exception such fetuses on careful microscopic examination showed degenerative changes. Hence, we must conclude that usually, except where the fibroid or fibroids are entirely subserous, abortion is the rule.

It is surprising to note the frequency with which absolute sterility is met with in comparatively young women who are perfectly normal with the exception of one or more fibroid nodules in the uterus. In my experience no form of treatment in such cases is of any avail. The fibroids in such cases

may or may not increase in size but conception does not occur. On the other hand the disappointment is all the greater when such a patient after years of sterility finally conceives and aborts early in spite of the greatest care to continue the pregnancy.

When pregnancy goes to term or near term in the fibroid uterus, one need not be apprehensive except in rare cases in which the fibroid nodule is cervical or at least so low down it will not rise out of the pelvis as pregnancy advances. A pregnant uterus disturbed by many fibroid growths may and usually does not give rise to trouble at the delivery while the cervical nodule by distorting the birth canal may make the labor extremely difficult. I recall a recent case seen in consultation in which the fetus died at the sixth month. The body of the fetus was expelled through the partially dilated cervix, the head being left above the nodule. All efforts to remove the fetal head from below were unavailing and necessitated a hysterectomy in a septic field. Fortunately, the patient survived after a stormy convalescence, but there might have been a different story. Looking back over such a history, one would have performed the hysterectomy early, as soon as the diagnosis of fetal death was established. However, on the whole more women and babies will be preserved by conservative treatment.

The danger of postpartum hæmorrhage in full term labor in the presence of uterine fibroids, is a real one. I have known of a number of instances in which the labor was perfectly normal, yet the woman died or almost died from imperfect uterine contractions. Uterine relaxation may occur even after the expulsion of the placenta, and extra precautions should be taken to guard such a patient from postpartum hæmorrhage. A number of years ago I had a good opportunity to observe the action or rather non-action of a fibroid uterus in which a cæsarean was performed for another indication. One becomes so accustomed to seeing efficient uterine contractions occur after the uterus is emptied by a cæsarean that it is humiliating, to say the least, to be unable to cause the empty uterus to contract with the organ within one's hands, but such was the case. All methods failed and I was compelled to remove the uterus to save the woman's life. It demonstrates how helpless we might be in certain cases when the manipulations are from below.

CONCERNING THE PREVALENT DENIAL OF FUNCTIONS LONG ATTRIBUTED TO THE GALL BLADDER[1]

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TWO radical conceptions of the gall bladder which have received considerable emphasis in recent years have had to do with negation of function: first, the denial that the gall bladder plays any significant rôle in digestion (12)—some authors even going so far as to assert that no bile which enters the gall bladder ever leaves it by way of the cystic duct (34, 20, 15)[2]; and second, the assertion that the gall bladder is a passive organ, and that insofar as bile leaves the reservoir it is expelled by extrinsic agencies (or the elastic recoil of enclosing walls) and not by the contractile force of the gall-bladder musculature itself (38, 18, 11).

The first of these views is no longer tenable and the second is fast succumbing to assault. But unfortunately these two negations have become so prevalent in recent years as to have occasioned widespread disbelief in the utility of the gall bladder; and this growing skepticism has resulted in the increasing resort clinically to unwarranted cholecystectomy; so that it is no longer uncommon to find reputable surgeons removing normal gall bladders with normal appendices when operating for hysterectomy or even in the course of exploratory laparotomies. As will be pointed out later, the result of this procedure (in addition to disturbances of the biliary duct system which it creates) is to deprive the patient of that considerable supply of concentrated bile which regularly initiates the digestion of meat and fat-containing foods at the beginning of every meal.

GENERAL OBJECTIONS TO THE THEORY OF A BILE RESERVOIR

Superficially viewed, many facts have seemed to support the denial of active function. For instance, it is generally agreed among surgeons that no one ever sees the human gall bladder contract during an operation. But the reasons for this are sufficiently obvious. First, there is no sustained stimulus for contraction, the stomach and duodenum being usually empty of food. Second, it has been shown that mechanical manipulation, chilling, and deep ether anæsthesia inhibit rhythmic contractions of the gall bladder (35). If, however, the abdomen is opened under local anæsthesia (as recorded in 2 instances by Matsuo, 30), contraction of the human gall bladder may be observed 5 minutes after the administration of magnesium sulphate. Also, in the abdomen of cats opened under local anæsthesia I have frequently watched contraction of the gall bladder lasting for several minutes after the intravenous injection of 0.001 milligram of adrenalin. This consists of a slow puckering of the surface, a characteristic bleaching of the wall due to its changing density, and a gradual withdrawal of the whole vesicle from the margin of the fossa in which it lies.

It is also true that fully contracted, normal, gall bladders are rarely if ever encountered in the operating room, but this is a direct consequence of not feeding patients before operations. Previous to the introduction of anæsthesia, however, empty gall bladders were frequently observed at autopsy. Even Galen knew that gall bladders were not of one size, but found them in his dissections of animals "sometimes very full, sometimes empty, and sometimes in an intermediate state" (17).

A notable exception to this is the gall bladder of the dog, which only partially empties after meals—usually not more than half its contents, although on one occasion I was able to induce the evacuation of all but 1 cubic centimeter of its contents by a mixed meal (Fig. 5B). Unfortunately this species is the one which has been worked upon more than any other, so that doubtless it was familiarity with this animal which led Carlson to conclude that "the rôle of the gall bladder as the storage organ for the bile has been greatly exaggerated" (12). This

[2] More recently this theory has been revived by Kaspar Blond (Klin. Wchnschr., 1927, xxxiv, 1606).

[1] Received for publication, June 17, 1927.

peculiarity of the canine gall bladder has never been explained, but quite likely it is a consequence of its relatively larger size as compared with that of man, the cat, and the guinea pig—3 species in which it completely empties after a meal of egg yolk. According to Wakerlin, the average volume of the bile reservoir of the dog is 15 cubic centimeters, whereas in man it probably averages less than 45 cubic centimeters. In 24 patients whom I have visualized, the estimated volume, excluding the neck of the gall bladder, averaged 30 cubic centimeters. The smallest one with which I have worked (Fig. 1) held 16 cubic centimeters and emptied nine-tenths of its contents in 16 minutes after a meal of egg yolk and cream. In the next 50 minutes it partially filled and thereupon emptied again. Whether the third filling was followed by emptying could not be ascertained (Graph C, p. 357, reference 8). It is not surprising, therefore, that complete evacuation of the gall bladder in dogs occurs only rarely. Nevertheless, the mechanism is capable of greater response, for Ivy has recently shown that the gall bladder of the dog can be virtually emptied by repeated intravenous injections of a highly purified "secretin." (See supplementary note, at end of article.)

Again, the relatively small size of the gall bladder has been seized upon as evidence that this organ could not hold all the bile that is secreted in 24 hours and that it could not therefore function as a storage organ. But we now know that no such demands are made upon it, for much of the bile secreted by the liver passes directly into the intestine: more or less continuously, for a time, following meals, and at longer intervals during fasting (2). Within the last few years it has also been shown that the gall bladder has great concentrating power (32) and that frequently it discharges part of its contents during fasting (6) and all or much of its contents after meals (4).

Another argument that is often cited is the fact that the gall bladder may apparently be removed with impunity. Yet cholecystectomy frequently results in well-recognized digestive disturbances (14), the first effect of extirpation being the dilatation of the extrahepatic ducts (24). Also, change in pressure conditions, after removal of the gall bladder, is said to predispose patients to an earlier appearance of bile pigment in the blood should the common duct become occluded (28).

Finally, congenital absence of a biliary reservoir in certain species of mammals has been cited as evidence that the human vesica fellea is useless,—notwithstanding the fact that no studies have ever been made upon the rate of flow of bile from the liver in such species. Yet it is conceivable that both the latent period of this flow and its rate differ from those in man and that these differences may be compensatory to the loss of a biliary reservoir. Furthermore, it has been shown that the bilirubin concentration of the bile taken from the common hepatic duct of an animal which has no gall bladder—the rat—is 8 times as great as that from the hepatic ducts of one which has a concentrating organ—the mouse (26).

As a corollary to this may be added a hitherto unpublished observation of the writer. Last spring I had the good fortune to find a clear case of congenital absence of the gall bladder in an anæsthetized cat with which I was working. After inserting a cannula in the common duct, sufficient yellow hepatic bile was collected to permit a colorimeter test by Folin of the Harvard Medical School to whom the sample was handed for analysis. When compared with a sample of yellow hepatic bile subsequently collected from the hepatic duct of a normal cat, the bile from the animal without a gall bladder was found to be 2.2 times more concentrated than the bile drawn from the hepatic duct of a normal cat. If we may judge from one case it would thus appear that when the gall bladder is lost early enough in fetal life, the deficiency is partly overcome by a compensatory mechanism.

All of which goes to prove the importance of a concentrating mechanism. Indeed it was the convincing demonstration of the concentrating function of the gall bladder by Rous and McMaster, in 1921, which initiated a reluctant return to the historical conception of the gall bladder as an important organ of digestion. A second step in this direction was made when the sequence of events following the eating of a meal was set forth.

THE EMPTYING OF THE GALL BLADDER AFTER MEALS

Although it had long been recognized by physiologists (16) that ingestion of mixed foods is followed by the entrance of bladder bile into the duodenum, it was not until 1923 that the matter was given an exact status by the discovery of a simple food (egg yolk and cream) which regularly and consistently empties the gall bladder of its fluid contents (3).

This information was obtained by the rather crude method of killing a large number of animals at regular intervals following meals. Two years later (4), on applying the new Graham method of cholecystography to this problem it was discovered that egg yolk and cream produced the same complete emptying of the human gall bladder (Fig. 2).

During the last year the writer has studied the effect of this diet on 24 healthy young men and women of the student class. In this large series of individuals, X-rays were taken at short intervals after food until the gall bladder shadows disappeared, then the changing volumes of bile were computed, and a contraction curve for each individual constructed (Fig. 3).

Only the fundus, body, and infundibulum of the gall bladder may be used for computation since the shadow of the neck is usually hidden and lies in another plane. In calculating volumes, the cholecystogram is divided by transverse lines into small circular plinths, the assumption being that the gall bladder is circular in cross section when under contraction, and the volume of each plinth then computed by the well known formula $\frac{\pi D^2}{4}$. The process may be considerably shortened by the use of graphic methods.

The standard meal adopted for patients was 5 raw egg yolks and half a pint of cream, the latter rendering the mixture more palatable, and perhaps accelerating the initial contraction. But egg yolk alone, both in animals and in patients, seems to be as effective as when mixed with cream. Since up to this time, it is the only discrete natural food which has been found to empty the mammalian gall bladder consistently and completely, it has been described in this sense as a specific food. But many fat-containing foods and meats have a considerable though lesser effect. Perhaps the greater efficacy of egg yolk is due to its emulsified form and to the fact that it is a complex mixture of fats and lipoids which is retained so long in the stomach that increments of it are being discharged into the duodenum for over 6 hours (in cats), thus keeping the gall bladder under stimulation for a considerable period, during which time it is usually emptied of all its fluid contents, although refilling and re-emptying may also occur.

In the course of this study many new facts about the human gall bladder have appeared. First, the discharge of bile from the gall bladder is intermittent in character, the first contraction phase being the most important one. Apparently, too, there is a sex difference in the evacuation of this organ—the female gall bladder being somewhat smaller, but discharging faster (after egg yolk) than that of the male (8). Thus in 12 young women, the quickest time in which the gall bladder discharged 1 cubic inch of bile averaged less than 20 minutes; whereas in 12 young men an average of 32 minutes was required, with the consequence that as much bile was discharged by the female gall bladder in the first half hour after a meal as by the male gall bladder in the first 45 minutes. In attempting to analyze these individual and sex differences it was found that the initial acidity of the stomach, the rate at which the stomach emptied, or the length of time required for a meal to pass through the intestinal tract did not affect the rate of emptying of the gall bladder (9). Chronic constipation and menstruation were also found to be without demonstrable effect.

One of the most striking features, however, is the very short latent period of contraction—usually less than 2 minutes after the ingestion of egg yolk and cream—almost simultaneously with the passage of food from the stomach (Figs. 2 and 3). Since the presence of bile in the duodenum is known to initiate the flow of pancreatic juice (Mellanby, Ivy), its discharge from the gall bladder at the very beginning of a meal has therefore a double significance.

As a result of these new observations it has become clear that the human gall bladder is designed to empty the bulk of its concentrated bile during the first hour of digestion, and that it completes its work, as a rule, before the secretion of bile from the liver reaches its maximum flow, 3 and 4 hours after a meal (6). There is provided, therefore, an integrating mechanism by means of which the intestine is supplied with an almost continuous flow of bile, from the moment that food enters the duodenum until the time when the last of the food leaves the stomach.

In spite of these facts, however, there are still investigators who claim that the lessening amount of bile in the gall bladder after meals is due to the concentration of bile within that viscus. In refutation of this, it is merely necessary to point to the speed with which the volume of the human gall bladder may be reduced—3 patients, for instance,

having discharged 1⅔ cubic inches of bile in the first 15 minutes of a meal (e.g. Fig. 3). Furthermore, in favorable cases, the presence of iodized bile in the cystic duct (Fig. 10B) may be observed in human cholecystograms (5, 6). If this be not sufficient, skeptical readers should employ Whitaker's method of filling the gall bladder of an experimental animal with iodized oil and watch the expulsion of oil under the fluoroscope (36).

INTRINSIC VERSUS EXTRINSIC FORCES

Notwithstanding this belated restoration of the gall bladder to a position of importance, many investigators are unwilling to admit that bladder bile is expelled by the contractile force of the tunica muscularis. The substitutes which have been offered are numerous, including respiratory and intra-abdominal pressures, the swelling of the liver during vasodilation, the pumping action of intestinal peristalsis, the recoil of the elastic wall of the distended gall bladder, and the flushing action of the hepatic bile as it enters and leaves the cystic orifice. Very recently it has been proposed that the matter be compromised by merely adding the action of the gall-bladder musculature to all these other factors, none of them being emphasized above the others (19). But as matters now stand it has been repeatedly shown by several investigators that expulsion of bile from the gall bladder can be induced experimentally when all these forces except the muscle tunic have been eliminated. It would seem, therefore, that those who advocate the considerable potency of any of these extrinsic forces are now in the same position as those investigators who formerly maintained, on insufficient evidence, that the gall-bladder musculature was the effective agent—namely, are called upon to demonstrate that the forces which they advocate can promptly discharge any considerable amount of bile without the aid of any other agency.

With this introductory statement it is now appropriate to consider the accumulated evidence upon which is based the assertion that the muscle tunic alone is sufficient to empty the gall bladder.

1. *Amount of muscle in gall-bladder wall.* There is sufficient smooth muscle in the wall of the gall bladder to expel the bile. In the biliary vesicle of the cat, for instance, there is as wide a tunica muscularis as in the small intestine of that animal—although the fibers in the latter organ are packed much thicker. Before we learned to induce emptying of the gall bladder by the use of appropriate foods, estimates of the thickness of the muscle tunic were made from sections of distended vesicles and obviously afforded inadequate means of comparison. Thus Hendrickson's studies on the musculature of the biliary tract have been quoted by those who were not familiar with the histology of this region to prove that there is only a small amount of smooth muscle in the gall bladder of the dog (11). But he prepared his specimens by injecting a macerating mixture "into the common bile duct until the walls of the gall bladder were distended." In Figure 5B a section through a contracted vesicle of a dog is shown, which demonstrates the substantial thickness of the smooth muscle tissue in this species. But even in fully distended vesicles, there can be no question as to the amount of muscle (Fig. 6).

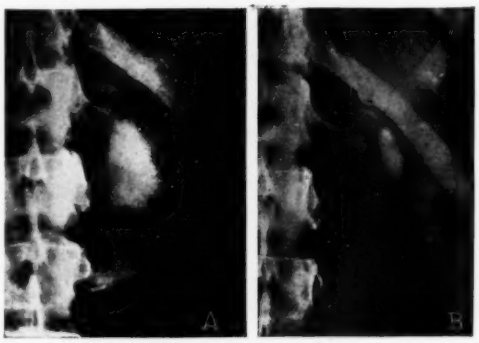

Fig. 1. Selected cholecystograms illustrating very rapid emptying of a small, female gall bladder (Case C. H. S.) *A*, 2 minutes after yolk and cream, volume, 16.4 cubic centimeters. *B*, 14 minutes later; volume, 1.5 cubic centimeters.

2. *Physiological studies of the tunica muscularis.* The muscle tunic of the gall bladder exhibits all the common physiological characteristics of smooth muscle, including the power of spontaneous rhythmic contraction. Since the classic experiments of Doyen in 1893, physiologists have repeatedly demonstrated rhythmic pressure changes within the

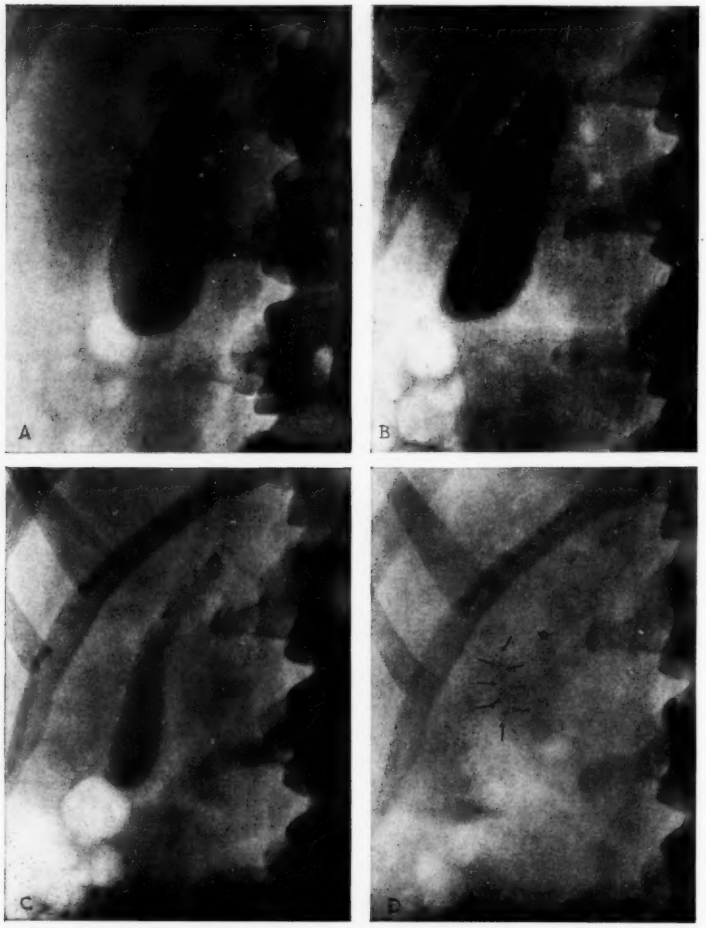

Fig. 2. Case C. L. B. Selected cholecystograms illustrating rapid emptying of the gall bladder in a young woman. *A*, 15½ hours after capsules; volume, 27.4 cubic centimeters. *B*, 2 minutes after yolk and cream; volume, 19.8 cubic centimeters. Note change in shape of fundus, indicating contraction. *C*, 16 minutes after eating; volume, 5.7 cubic centimeters. *D*, 65 minutes after eating; volume, 0.33 cubic centimeters. At 80 minutes after eating, no shadow was visible.

gall bladder which can be attributed to one source only, the activity of the tunica muscularis. Beginning with Doyen, graphic records of these contractions have been obtained by introducing balloons attached to various kinds of manometers, the gall bladder being either *in situ*, or separated from the liver or even removed from the body. These studies have been supplemented by experiments testing the action of drugs upon strips of gall-bladder muscle isolated in physiological salt solution. In most of the cases in which it was observed *in situ*, care was taken to prevent contact with adjacent viscera and to eliminate respiratory pressures. Using such methods in dogs, Bainbridge and Dale (1) established the rate of contraction as 1 to 3 undulations per minute. Okada (31) found it to be from 2 to 5 per

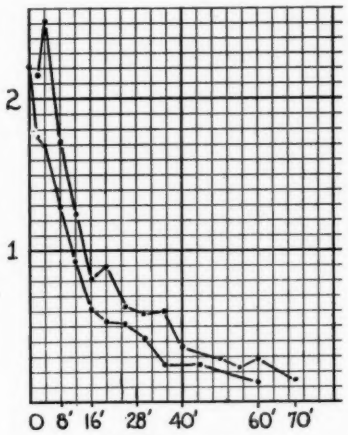

Fig. 3. Two contraction curves made from the same individual (Case N. B. B.), illustrating the precision with which the human gall bladder responds to a meal of egg yolk and cream. The curve at the left was reconstructed from X-rays made with the patient lying continuously upon a table. The one at the right was made 2 months later with the table rotated to a vertical plane and with the patient continuously in an upright position. For original X-rays, see Figure 7. In other respects the conditions were constant. Apparently gravity does not affect the rate of emptying. Incidentally this series represents the fastest emptying time recorded in any young man. Ordinates represent cubic inches of bile; abscissas, time in minutes after a meal of 5 egg yolks and a half pint of cream; periods (in contraction curve), successive X-rays. For data on rate of emptying of stomach and intestine, in this individual, see Figure 1 (N. B. B.), bibliography: 9.

minute, but noted that the rhythmic activity was much more marked following a meal of horse meat. In the most recent study, that of Taylor and Wilson (35), the rate was placed at from 2 to 6 contractions a minute, i.e., somewhat faster than that of the stomach. These authors brought out the further interesting facts that the gall-bladder rhythm was very sensitive to such conditions as chilling, anæsthesia, and manipulation of either the organ itself or the duodenum; but that intravenous injections of adrenalin greatly increased the amplitude of the contractions. This latter observation is very significant and is in accord with the writer's discovery that intravenous injection of adrenalin causes more pronounced momentary expulsion of iodized oil from the gall bladder than that of any other drug—the contraction being visible to the naked eye in animals with the body cavity opened under local anæsthesia.

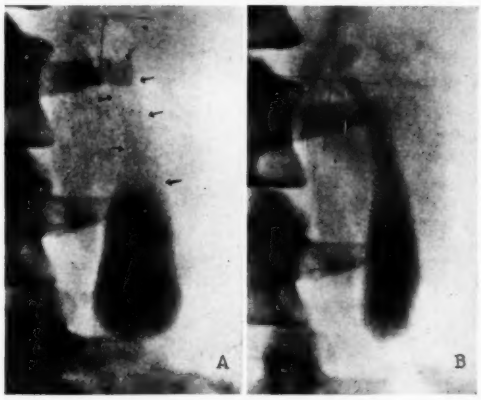

Fig. 4. Selected cholecystograms of a young woman (Case A. H. H.), showing change in shape of gall bladder after a meal of egg yolk and cream. Patient X-rayed in upright position continuously, for several hours after eating. *A*, 2 minutes after eating; volume, 36.7 cubic centimeters. Note sagging shape and greater concentration of dye in body and fundus. *B*, 13 minutes later; volume, 16.5 cubic centimeters. Note more uniform density and shape of gall bladder at 15 minutes after eating. Also note the rapid rate at which it empties against gravity.

3. *Changes in shape following meals.* A third line of evidence is the change in shape which the gall bladder undergoes following meals—a change which can be interpreted as due only to contraction. This has been demonstrated both in the human body and in animals. In X-rays of the human gall bladder the first significant change usually appears in the fundus (Figs. 2 and 4; see also earlier papers, 5). Previous to a meal the pear-shaped sack appears relaxed as if sagging under the weight of the iodized bile. But often within 2 minutes after a meal the fundus narrows, as if the bile were being lifted by compression from the bottom. Sometimes this is sufficient to reverse the shape of the organ—the fundus becoming narrower than the body.

The writer cannot advocate strongly enough the importance of X-raying patients after meals as well as before, as a routine procedure in roentgenological departments. The simplest method would be to have pictures made every 5 minutes during the first half hour after the patient drinks a pint of milk. This diet would not completely empty the gall bladder but would cause the first and most important phase of contraction, when the gall bladder delivers over half of its contents (6). There are several reasons for adopting this procedure: first, to test the

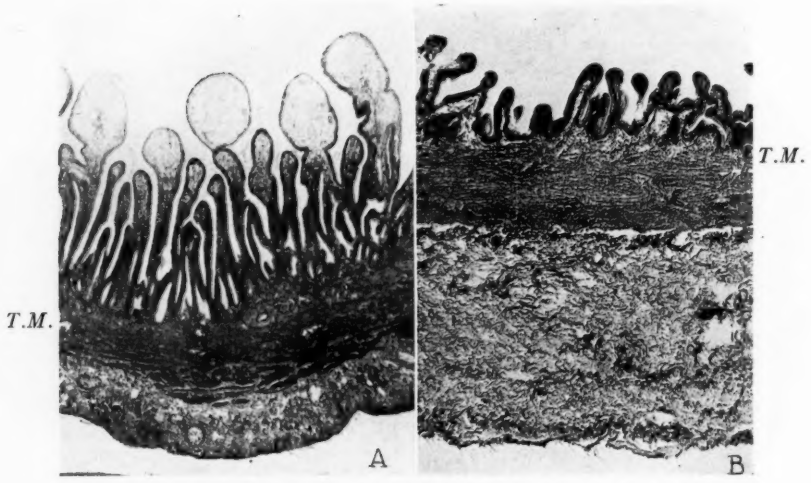

Fig. 5. Photomicrographs illustrating thickness of muscle tunic, *T. M.*, in contracted gall bladders. *A*, from a cat 6½ hours after a meal of egg yolks and cream. Incidentally this illustrates the first stage in the formation of "white bile." Note œdematous swelling of villi of mucosa; the gall bladder, however, contained no fluid nor residue of any sort. *B*, from a dog 3 hours after a meal of egg yolk and meat. Gall bladder contained 1 cubic centimeter of yellow bile. Note differing proportions of 3 tunics as compared with those of the cat (*A* and *B*, same magnification).

contraction rate; second, for the purpose of interpreting the normal shape of the gall bladder; and third, as a means of detecting abnormalities and adhesions (7). During fasting the gall bladder is usually flaccid and its shape subject to distortion by surrounding organs. As soon as contraction sets in and bile is expelled, it rounds up and tends to straighten out, often revealing the neck and cystic duct (Fig. 10).

In animals, the contraction of the gall bladder has been studied by a variety of methods. Whitaker, working with cats and employing his own iodized oil method, has published X-rays which show constrictions in the neck, body, and fundus of the gall bladder, following a meal of egg yolk (Figs. 8 and 9). He also observed these changes taking place under the fluoroscope (36). Higgins and Mann, having opened the body cavity of the guinea pig under local anæsthesia, observed the gall bladder for several hours as it diminished in volume after a meal of egg yolk. They noted that at first there were several centers of contraction which induced a variety of patterns; but that later these independent areas gradually merged to effect the reduction of the whole organ (21). Subsequently they found that stimulation with an induction current produced marked contraction of the gall bladder (22).

4. *Critical experiments.* Actual expulsion of the contents of the gall bladder in response to smooth muscle drugs, adrenalin, and food have been recorded under experimental conditions which rule out the action of extrinsic forces. McMaster and Elman (27), for instance, excluded these factors by means of an ingenious system of triple intubation, 3 separate tubes being installed in one animal—the first in the cystic duct, the second in the upper part of the common duct, and the third in the lower part of the choledochus. After feeding the animal they were thus able to record, simultaneously, the flow of bile from the gall bladder into a manometer, the amount of bile secreted by the liver, and the resistance to the passage of bile offered by the intestinal wall. An important feature of their work was the fact that these tubes were installed at least 10 days before the experiment, the tubes being so connected during this interval that no disturbance of function resulted from the operation. The dogs were then trained to co-

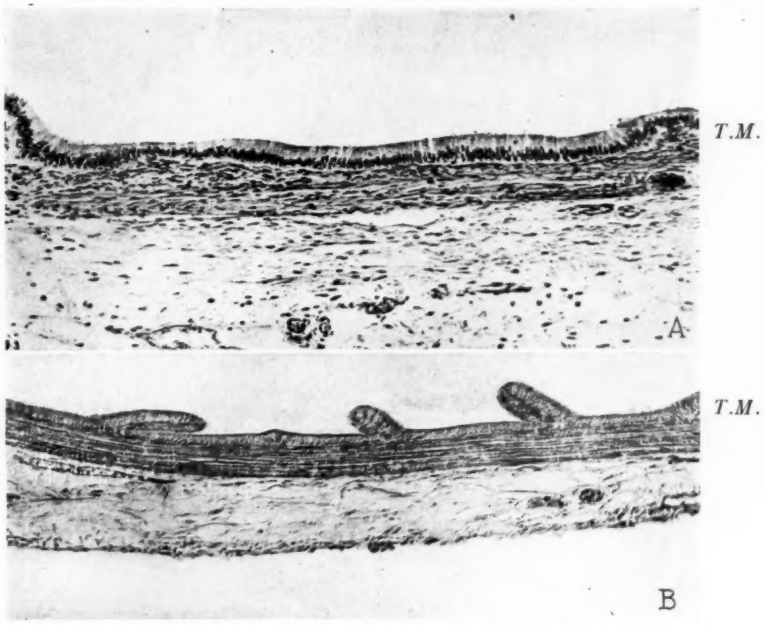

Fig. 6. Photomicrographs illustrating thickness of muscle layer, *T.M.*, in fully distended gall bladders. *A*, from a 9 months old child (by courtesy of Dr. Halpert). *B*, from an adult cat (*A* and *B*, same magnification).

operate and were in normal condition at the time of the experiment. Under such favorable conditions these investigators were able to demonstrate the sequence of events following the ingestion of food. They found that immediately after eating there was an abrupt increase in pressure within the gall bladder (100 to 125 millimeters of bile) and simultaneously a relaxation at the duodenal orifice of the common duct. In an accessory experiment on the same animal they measured the amount of bile emerging from the intubated gall bladder instead of recording the pressure changes by a manometer. In contrast to the abrupt emergence of bile from the gall bladder, there was no immediate increase in the flow of bile from the liver, and when it did begin it was gradual. Since Kelling had shown that 300 grams of food could be eaten by a dog without increasing the intra-abdominal pressure, owing to a compensatory relaxation of the abdominal muscles, intra-abdominal pressure was not a factor in the expulsion of bile from the gall bladder. Nor could it be attributed to the flushing action of hepatic bile nor to the sucking action of peristalsis, since the manometer tube was connected to the cystic duct only. The conditions of the experiment, therefore, permit but one conclusion, namely, that the bile was expelled from the gall bladder by the action of its muscular tunic in response to the ingestion of food.

Balloon experiments with the gall bladder of the dog have been a favorite pastime of physiologists and surgeons up to the present writing. Many who have restricted their observations to manometer readings have inferred that the pressure changes induced by the admitted contraction of the gall bladder around the balloon were not sufficiently great to expel the bile. But they have not taken into consideration the damaging effect of all forms of general anæsthesia upon gall-bladder action, nor the quantitative difference which quite likely distinguishes the contraction in the dog from other species, such as man, in which the whole viscus has been known to empty in 15 minutes (Fig. 1). In the opinion of the writer, the work of McMaster and

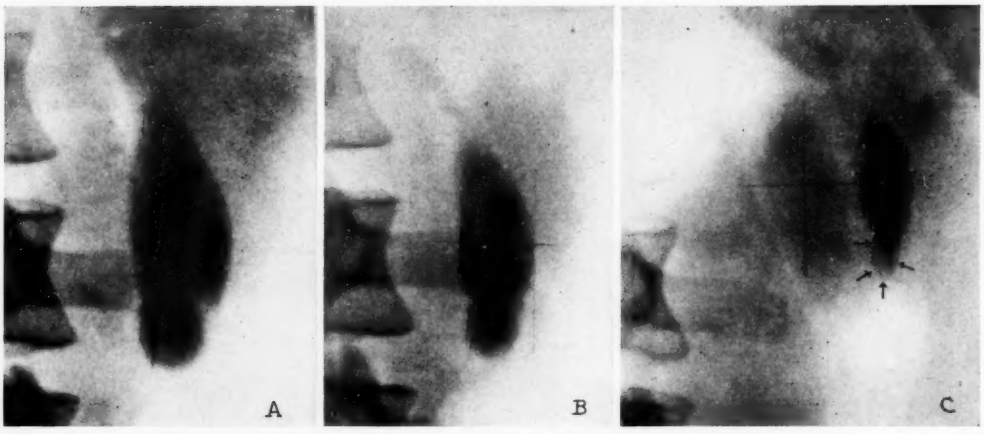

Fig. 7. Selected cholecystograms from Case N. B. B. shown in Figure 3 (right curve), illustrating marked contraction of the fundus, notwithstanding the fact that this series was made in a standing position. *A*, 8 minutes after eating yolk and cream; volume, 28.2 cubic centimeters. *B*, 16 minutes after eating; volume, 13.3 cubic centimeters. *C*, 50 minutes after eating; volume, 4.7 cubic centimeters. Before eating, the fundus was wider than the body of the gall bladder.

Elman on dogs stands out above all others in the ingenuity of the experiment, in the superiority of the conditions under which the dogs were tested, and in the fact that they observed the actual expulsion of bile and relied not merely upon pressure changes.

Similar conclusions were reached by Higgins and Mann (21), in a careful investigation employing somewhat different methods. Having trained dogs to lie on the operating table quietly for several hours, they opened the abdominal cavity under local anæsthesia and observed the emptying of the gall bladder under conditions in which every factor but the action of the muscle tunic had been excluded. The sucking action of peristalsis was eliminated by inserting a rubber catheter into the common bile duct, so that bile flowed into a manometer and not into the duodenum. Any flushing of the gall bladder passages by the liver bile was prevented by tying all the hepatic ducts.

Higgins and Mann also disproved the efficacy of respiratory pressures by ingeniously demonstrating the emptying of the gall bladder in vertebrates which breathe by gills and not by the rhythmic action of the diaphragm. Electing to work with the gar-pike, an ancient armored fish of the Mississippi Basin, they fed these animals with egg yolk, kept them quiet, and at necropsy found the gall bladder collapsed. Obviously the gall bladders of these fishes were not emptied by external pressures. To these same authors, also, belongs the credit of establishing the contractility of the gall bladder in the guinea pig (see recent summary of the physiology of the extrahepatic biliary system in this animal, 23).

About the same time that these two groups of investigators were reaching independent but similar conclusions about the emptying of the gall bladder in dogs and guinea pigs, Whitaker (36) and the writer (5) were accumulating data which seemed to show that the gall bladder of cats also emptied by virtue of the contractile force of its muscular tunic. For it was found that marked expulsion of iodized oil could be induced by the intravenous injection of smooth muscle drugs. In addition, Whitaker showed that a barium meal mixed with egg yolk could be moved through the whole intestinal tract by peristalsis without causing the discharge of a single drop of bile from the gall bladder (series 3, 1 c.)—a circumstance which could not have occurred if Burget's theory of the sucking action of peristalsis (10) had been correct. Recently the writer has confirmed this on a human case. On the positive side Whitaker showed that

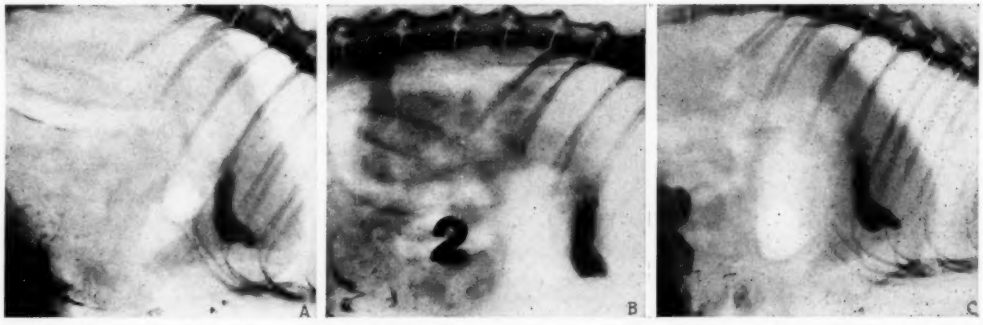

Fig. 8. X-rays of an experimental animal (Cat 1), in which the gall bladder was filled with lipiodol and the bile duct severed so that iodized oil was leaking out into the body cavity at the time the abdominal wall was sutured. *A*, 2 hours after the operation. Note iodized oil in the body cavity. *B*, 4⅔ hours after operation. Gall bladder not yet emptied, notwithstanding the fact that the bile duct has been severed. *C*, 15 minutes after meal of egg yolk. Note bile in cystic duct.

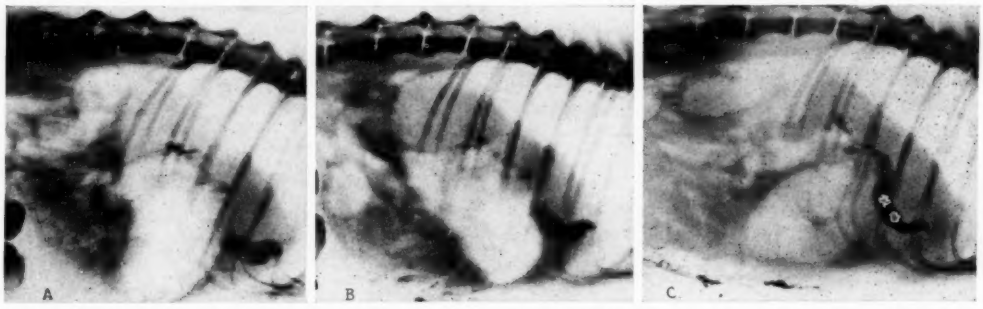

Fig. 9. Experiment similar to that shown in Figure 8, excepting that a funnel was placed in the severed end of the common duct to insure free exit of bile into the body cavity (Cat K). *A*, One-half hour after operation. *B*, 3½ hours after operation. Iodized oil stuck in the common duct is the same as that seen in *A*. Gall bladder has emptied little if any during this time. *C*, 40 minutes after egg yolk. Note constriction in the fundus of the gall bladder and continuous column of oil from the fundus to the end of the common duct, showing response to food in spite of the fact that the connection of the gall bladder with the duodenum has been interrupted (cf. figures, reference 9).

when the wall of the gall bladder was damaged by squeezing it with clamps, the viscus failed to empty in proportion to the amount of injury. Obviously the action of intra-abdominal pressure upon the gall bladder would not have been interfered with by this procedure. And within a few months Spurling and Whitaker (33) have shown that patients who were subjected to operations for drainage of the gall bladder (merely cholecystostomy) never recovered the ability to empty the gall bladder—the inference being that the muscle tunic was permanently impaired.

Continuing the work on cats, the author sought to eliminate by two methods every factor but that of the gall-bladder musculature. The first of these (5) consisted in filling the gall bladder with iodized oil and then tying the common duct just below the entrance of the cystic duct. Since several hepatic ducts opened below the point of ligation, the animals did not become jaundiced. But tying the duct eliminated the effect of intestinal peristalsis and sphincter action. Also since no bile could escape from the gall bladder into the intestine, many experiments could be tried on the same animal (starting with the gall bladder in the same state of distention) thus permitting a comparative study of different reagents. The day after the operation, when the cats were in good condition, purring and moving about, the gall bladder was X-rayed.

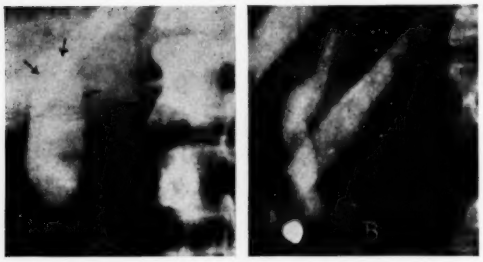

Fig. 10. Selected cholecystograms illustrating expulsion of bile into the cystic duct after ingestion of cream (Case L. O. M.). *A*, 20½ hours after dye (fasting condition); volume, 46.7 cubic centimeters, excluding ampulla. *B*, 30 minutes after taking a half pint of cream; volume, 12.6 cubic centimeters, excluding the bile in the cystic duct. (White circle over the fundus is an undissolved pill in colon.)

No changes in shape occurred before the experimentation, showing that intra-abdominal or respiratory pressures or elastic tissue in the gall-bladder wall were unable to raise the column of heavy iodized oil. But as soon as food was given, the gall bladder elongated, sustaining the column of heavy oil for 4 hours. It was also found that skin irritation (such as was induced by shaving the animals' legs), or protein shock (caused by blood transfusions), also produced a temporary elongation, as did intravenous injections of smooth muscle drugs and adrenalin — the latter causing marked expulsion of the oil into the cystic duct against the secretory pressure of the liver.

In a recent series of experiments the same results were sought by another method. At the time that the gall bladder of the cat was filled with iodized oil, the common duct was either severed or slit open, or a cannula introduced so that the contents of the gall bladder could empty freely into the peritoneal cavity. By thus interrupting the common duct, any possible pumping action of intestinal peristalsis was prevented. In each case before the body cavity was sewed up, it was ascertained that bile and iodized oil (which had just been injected into the fundus of the gall bladder) were leaking out of the incision in the common duct. But in no instance did the gall bladder empty the day of the operation as would have been the case if elastic tissue or intra-abdominal pressure or the sluicing action of the hepatic bile had been effective. Each time some special form of stimulation was required. When that was applied, the gall bladder responded (Figs. 8 and 9).

The suggestion may be advanced by those who are familiar with the recent work of Luetkens (25) that the failure of the gall bladder to empty in these animals after the duct is severed is due to a spastic contraction of the neck of the organ, induced by operative shock. This presupposes a special thickening of the circular muscle to form the so-called "collumcysticus sphincter." But longitudinal sections of the cat gall bladder, made with this purpose in view, show no increase of thickness in the circular muscle of this region. Also Dr. Halpert informs me that the same is true of the human gall bladder, and that if anything the muscle of this region is thinner.

The writer has placed considerable emphasis on this capacity of the gall bladder to respond to food stimulation when its connection with the duodenum has been severed, on account of the persistent efforts of certain investigators to explain the discharge of bladder bile as due primarily to the opening of the sphincter at the outlet of the common bile duct or to the mechanical action of intestinal peristalsis. Burget (11) has even attributed the emptying of the gall bladder to lowered tonus of the duodenum caused by the presence of fat in that portion of the intestine. Yet having thereby called attention to the lessened effectiveness of the intestinal muscle after a fat meal he nevertheless retains intestinal peristalsis as the chief evacuating mechanism of the gall bladder. Equally illogically, those who have sought to minimize the action of the gall-bladder musculature, have been most insistent in denying the existence of a sphincter at the end of the common duct. If both of these contentions were true the remarkable precision with which the human gall bladder responds to the ingestion of food (Fig. 3) would be utterly inexplicable. Fortunately it is not necessary to accept either hypothesis. Within a few months Mann and Higgins (29) have demonstrated a sphincter action of that portion of the common duct in the dog, which lies some distance behind the papilla, thereby nullifying the conclusions of those investigators who have sought to establish the fact that the filling and emptying of the gall bladder were controlled by the intestinal mus-

culature after the sphincter papillæ had been removed.

In conclusion, therefore, it seems reasonable to assume that in the cat, dog, guinea pig, and man, bile is expelled primarily by the contractile force of the muscle tunic of the gall bladder. With this fact assured, the immediate problem of the future is to find that mechanism by means of which the gall bladder musculature itself is activated, and how the flow of bile from the common duct is regulated.

SUPPLEMENTARY NOTE.—Since this article was submitted, several important contributions to this subject have appeared in the literature. Chief among these is the convincing demonstration by Ivy (Proc. Soc. Exp. Biol. & Med., 1927, xxv, Nov.), that evacuation of the gall bladder in the dog may be secured by intravenous injections of a highly purified "secretin." This seems to establish the fact that after food, contraction of the gall bladder is sustained by a humoral mechanism originating in the mucosa of the small intestine.

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UNILATERAL RENAL APLASIA[1]

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THE condition which we wish to discuss is renal aplasia or defective development of the kidney. It is a subject of interest from the point of view of embryology, and also as an anatomical anomaly.

The functionless kidney is of general interest to the surgeon and internist but it is of special interest to the urologist, and for this reason, we wish to present 6 cases, which we have had in the urological service of the Royal Victoria Hospital. These cases may all be classed as developmental defects. Other causes of functionless kidney, such as tuberculosis, calculus, or a closed pyonephritic lesion need not be discussed here.

Five of the patients are living, and we had the opportunity to examine clinically the other one before death. In the series we find that the diseased condition ranged from complete absence in one case to hypoplasia in two others. When we look at the embryology for a moment we can see that there is ample room for such variation in the rudimentary organ.

In complete absence of the kidney there is evidently a lack of formation of the renal bud from the wolffian duct. Complete absence is reported by Anders in about 1 case in 1,800, and by Motzfeld in 1 case in 1,000. There are some 350 to 360 cases reported in the literature and from our series we can add one to the list. Many of these patients show some abnormality in the genital tract. Moore states that "of 226 cases examined, in 75, 33 per cent, more or less extensive congenital defects of the genital organs are recorded." In the male there is evidently a defect in the formation of the wolffian duct itself, and in the female an associated defect in the muellerian duct.

A defect at a later period in embryonic life would bring about the condition frequently seen in cases of absent kidney—that of normal genital formation with a normal bladder and ureteral orifices, but with a short rudimentary ureter, which may or may not be patent. The short rudimentary ureter is fairly frequently found, and quoting Anders again, he states: "Out of the whole number of 286 cases reported, the ureter was completely absent in 240 cases. In 24 instances a more or less rudimentary ureter was in evidence without the slightest indication of the presence of renal structure." The defect in this latter instance would, no doubt, be due to lack of development of the nephrogenic tissue, the precursor of the secretory portion of the kidney, associated with a defective development of the ureter bud, and the failure of division into primary and secondary tubules.

In some of these cases a mass of connective tissue has been found in the region where the kidney should normally lie but no mention has been made of the finding of any evidence of renal tissue (Lewis, Gilmore). It is reasonable to suppose that this defective development, whatever it may be due to, could occur at a slightly later period in embryonic life and leave some traces of fetal or partially developed renal tissue without forming in any way what could be called, anatomically, a kidney. Three of our cases are of this type.

A defect arising at a later period would leave a more perfectly formed kidney, which may or may not function. These are of the type classified as hypoplasia. Many such cases have been reported in the literature and two in our series would fall in this class.

Such defective development has been considered by Coplin to be due to defective arterial development and coincides probably with the work of Bagg on congenital defects in X-rayed mice. Bagg has given many instances of absent and rudimentary kidney following this method. In some animals the rudimentary kidney was no larger than the head of a pin, while in many it was completely absent.

Whatever may be the anatomical findings in each individual case, each one is non-functioning, and the diagnosis of such a condition is of extreme importance to the urologist. For,

[1] Read at the New York Academy of Medicine, Section of Urology, March 16, 1927.

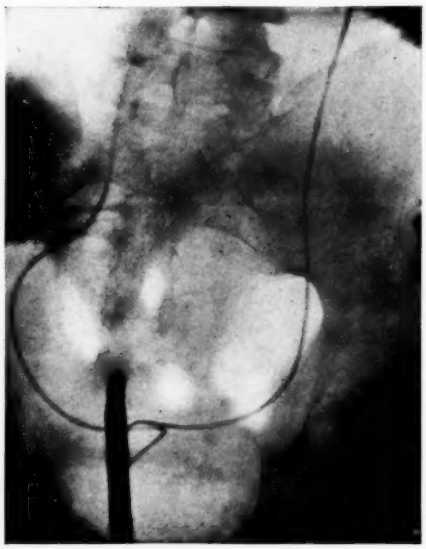

Fig. 1. X-ray of Case 2 showing left catheter in renal pelvis and right catheter obstructed at sacro-iliac synchondrosis. No shadow seen which would suggest a calculus.

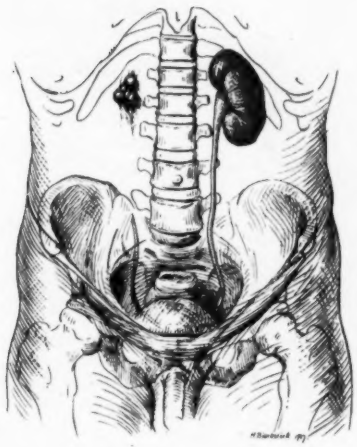

Fig. 2. Schematic drawing showing nodules of rudimentary renal tissue in right kidney region of Case 2. Nodules connected by fibrous bands. Lower portion of ureter patent to sacro-iliac synchondrosis. Upper portion not found at operation.

under the stress of carrying on all the excretory function, the sole kidney becomes damaged whether by nephritis, calculus, or infection. Ballowitz stresses the frequency of calculus formation in the solitary kidney while the combined statistics of Ballowitz, Moore, and Anders indicate that a greater than the normal percentage among subjects of congenital single kidney, die of kidney complaints. Anders also found that in 42 per cent of the cases in his series, the single kidney showed advanced lesions of chronic nephritis.

Throughout this discussion, we have used the term "aplasia" to mean incomplete development. This we believe would also include both the absent and the rudimentary kidney. The differentiation being only a matter of degree.

The cases we have to report are as follows:

CASE 1. Mrs. P. L., age 19, Case No. 59124. She was admitted to the hospital July 16, 1926, suffering from pain in the right lumbar region, of 4 days' duration. The attack had commenced with aching pain in the right lower quadrant of the abdomen, followed shortly by similar pain in the right lumbar region, and more acute attacks radiating down the right leg. The following day the patient developed fever and chills and a frequency by day, every half hour; voiding small quantities and with marked burning of urination. She gave a history of right-sided pain with fever and chills during her first pregnancy, 3 years previously, but had no such symptoms during the second. She was admitted to the hospital on the day following the onset of her symptoms, and on examination appeared to be in marked pain, with frequent rigors and a temperature of 103 degrees. There was marked tenderness in the right costolumbar angle, also over the whole right side of the abdomen. The right kidney was easily palpable, enlarged, firm, and tender. The left kidney was not palpable nor tender. There was no abnormality of the external genitalia. The urine was cloudy; straw colored; 1010, specific gravity; and acid in reaction albumin+; sugar 0. Microscopically there were present epithelial cells, motile bacilli; pus++ but no red blood cells or casts.

One cubic centimeter of phenolsulphonephthalein, intramuscularly gave: first hour, 10 per cent; second hour, 25 per cent; total, 35 per cent.

On cystoscopy the bladder mucosa was found to be slightly inflamed. The right ureteral orifice was normal in position and appearance but the left was not made out. The right ureter was catheterized to the renal pelvis, and a specimen was obtained which showed microscopically: epithelial cells; pus ++;

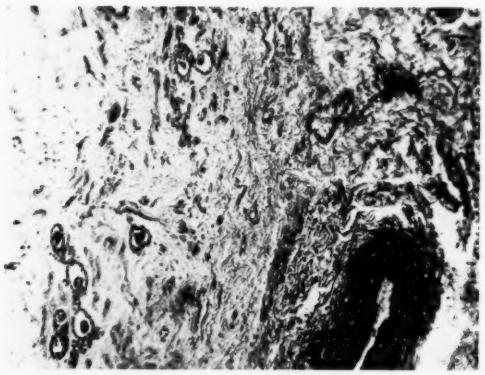

Fig. 3. Rudimentary uriniferous tubules in a mass of connective tissue. Cells are flattened and several tubules contain casts. A thick walled vessel seen in the other portion of the section. No glomeruli were found in this specimen. Case 2. Low power.

Fig. 4. X-ray taken at time of cystoscopic examination in Case 3, showing right catheter well up but left catheter obstructed just below sacro-iliac synchondrosis. No shadow seen suggestive of calculus.

few red blood cells and colon bacilli. X-rays with catheter in the right ureter showed the tip of the catheter at the level of the third lumbar vertebra. No shadow was made out which would suggest calculus. A large right kidney shadow was noted, with no evidence of any kidney shadow on the left side.

The condition remained unchanged with a temperature ranging between 104 and 105 degrees. The following day a decapsulation and nephrotomy was performed. It was noted then that the kidney was approximately double the size of a normal kidney. No abnormality of the vessels was noted. She was discharged 3 weeks later with the wound healed. The renal function, as shown by the penolsulphonephthalein test (1 cubic centimeter intramuscularly), giving first hour, 40 per cent, second hour, 30 per cent, total, 70 per cent.

She was readmitted 2 months later still troubled with pain in the right side; some tenderness over the bladder; and a frequency by day, 5 to 6 times; night, once, accompanied by burning urination.

On examination this time there was tenderness in the right costolumbar angle; and the right kidney was enlarged, firm, and tender. There was slight tenderness along the course of the right ureter and over the bladder. The urine was clear; straw colored; 1010 specific gravity; acid, a faint trace of albumin was present but no sugar. Microscopically, there were scattered pus cells and some epithelial cells. The phenolsulphonephthalein test (1 cubic centimeter intramuscularly) gave first hour, 50 per cent, second hour, 20 per cent, total 70 per cent.

The blood urea findings were normal. Blood urea, .420 grams per liter of blood; blood urea nitrogen, 19.6 milligrams per 100 cubic centimeters of blood; creatinin, 1.29 milligrams per 100 cubic centimeters of blood. Cystoscopy at this time showed the bladder mucosa to be slightly inflamed and granular. The right ureteral orifice appeared normal. The left ureteral orifice could not be found. In fact there seemed to be an absence of the trigonal ridge on that side. The right ureter was catheterized to the renal pelvis, and clear amber urine was obtained, containing a few red blood cells and white blood cells. Culture of this specimen gave no growth. A pyelogram with 4 cubic centimeters of 12 per cent sodium iodide solution in the right pelvis showed a very large kidney shadow, with only a partly filled large renal pelvis. Indigocarmine injected intravenously appeared from the right side in 2.5 minutes but none appeared from any portion of the left side of the bladder or urethra.

CASE 2. Mr. H. W., age 31, admitted July 30, 1925. When he was admitted to the hospital, he complained of a frequency which he had suffered from for the last 2 years. Four days previously he had an attack of colic-like pain on the right side and later, from that time on he had burning on urination. He gave no other history of symptoms: As a child he had suffered from infantile paralysis, also scarlet fever, mumps, and chickenpox. His general examination was negative apart from some atrophy of the left leg, and paralysis of the muscles below the knee. The blood pressure was 120-80.

Examination of the genito-urinary system showed no costolumbar tenderness; the kidneys were not palpable; there was slight ureteral tenderness on the left side, but none on the right. There was no suprapubic tenderness or distention. External genitalia

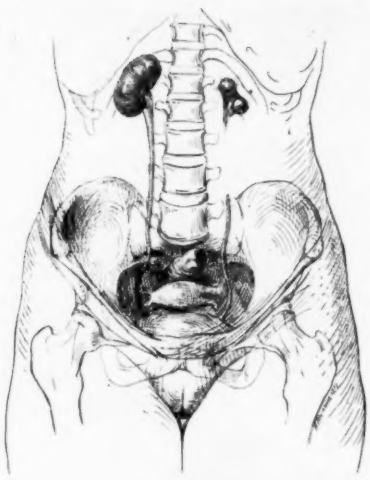

Fig. 5. Schematic drawing showing two cysts connected by fibrous bands in Case 3. Lower portion of ureter patent, upper portion absent.

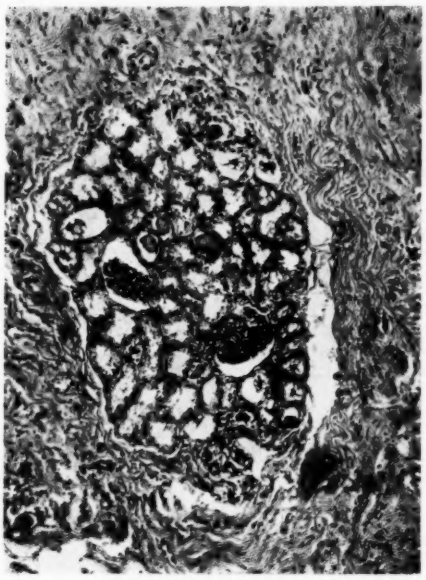

Fig. 6. Photomicrograph of section from cyst wall in Case 3. Connective tissue predominates, with here and there nests of partially and completely developed tubules and glomeruli. Several of the tubules contain casts. Low power.

and prostate were normal. His urine was clear straw colored; specific gravity, 1020; and some albumin was present but no sugar. Microscopically there was pus, bacilli motile; epithelium, and calcium oxalate crystals.

His renal function by the phthalein test, intramuscularly given, was apparently normal: first hour, 55 per cent; second hour, 15 per cent; total, 70 per cent. Blood Wassermann was negative. No tubercle bacilli were demonstrated in the bladder urine on several examinations.

X-ray of the kidney and bladder region showed a small round shadow opposite the fifth lumbar vertebra on the right side.

At cystoscopy, the bladder mucosa was found to be slightly inflamed. The ureteral orifices in normal position appeared slightly gaping. The left ureter was catheterized to renal pelvis and a specimen was obtained. The right ureter could be catheterized for only half the distance and no specimen was obtained. The specimen from the left kidney showed an occasional red and white blood cell, and a few epithelial cells, and culture gave a growth of bacillus coli communis. X-ray with catheters in position showed the left catheter up in the renal pelvis, but the right only at the sacro-iliac synchrondrosis. No shadows were seen suggestive of calculus or of the previously noted shadow. A second cystoscopy confirmed these findings, also indigocarmine injected intravenously appeared from the left side in 5 minutes, but none from the right side in 15 minutes (Fig. 1).

The diagnosis was made of a probable closed tuberculous lesion of the right kidney and operation was performed on August 6, 1925. On exposing the right kidney only a small mass of fat and fibrous tissue was found, containing several small nodules of a firmer tissue. Attached to these were several small blood vessels. No ureter could be found. The mass of tissue was removed from a small indefinite pedicle. There was no other evidence of kidney tissue (Fig. 2).

Report of examination by Dr. Waugh of the Pathological Department was as follows: Specimen consists of a mass of reddish tissue of rubbery consistency, about 30 grams in weight. At one end is a cyst with a smooth pale wall. It is the size of a small walnut.

Sections of the tissue show it to be made up of an irregular mass of loosely arranged fibrous connective tissue containing numerous larger and smaller blood vessels. There are occasional peculiar, duct-like structures, containing blue staining, more or less homogenous material, and lined by small irregular cells, having little resemblance to epithelium, but probably being atrophic, degenerated and necrotic undifferentiated lining.

The cyst wall consists of a wavy fibrous connective tissue, without epithelial lining. Hyaline fusion of the fibrous connective tissue is occasionally seen. There

Fig. 7. X-ray taken at cystoscopic examination in Case 4, showing right catheter obstructed about 3 centimeters beyond ureteral orifice, and at the left about fourth lumbar vertebra. No shadows seen suggestive of calculi.

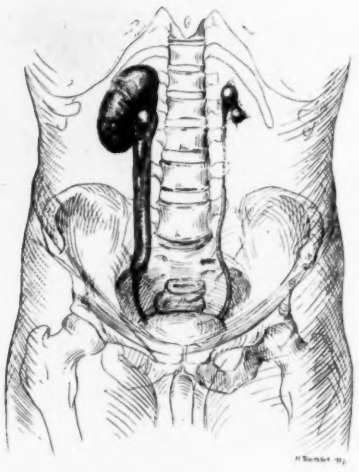

Fig. 8. Schematic drawing of Case 4 showing nodules of aplastic kidney tissue in left renal region. Lower portion of ureter patent, the upper represented by a fibrous cord connected with these nodules. Stricture of ureter in lower portion of right ureter with hydro-ureter and hydronephrosis present.

is no evidence of inflammatory changes in the tissue:

Diagnosis: aplasia of kidney (Fig. 3).

The patient developed bronchopneumonia about 10 days after operation but soon recovered. When heard from 6 months later, he was free from symptoms, had gained in weight and strength, was able to go about his work as usual. He has had no recurrence of pain on the right side since his operation.

CASE 3. Mrs. D. F., age 33, was admitted to hospital complaining of severe pain in the left loin which had awakened her from sleep 4 days previously.

Frequency by day five or six times and night once, had appeared 2 days later. Slight burning accompanied urination. She gave the history of having had an attack of acute pyelitis on the right side 4 years previously, and had suffered from a slight dragging pain on that side for the past 6 months. She had one child, 10 years of age, alive and well. On examination her general condition was normal. Blood pressure was 120–70.

Examination of the urinary system revealed no costolumbar tenderness. The kidneys were not palpable and there was no tenderness over the kidneys nor along the course of the ureters. There was no suprapubic distention or tenderness. The genitalia were normal externally and by vaginal examination.

The urinalysis showed urine of a hazy straw color; specific gravity, 1028; reaction, acid; no albumin or sugar; epithelial cells, a few white blood cells, and a few motile bacilli. No tubercle bacilli were found in the bladder urine. X-rays of the kidney and bladder region were negative for calculi.

One cubic centimeter of phenolsulphonephthalein given intramuscularly, and 65 per cent was excreted in 2 hours.

The blood urea findings were normal. Blood urea, .288 gms. per liter of blood; blood urea nitrogen, 13.4 milligrams per 100 cubic centimeters of blood; creatinin, 1.29 milligrams per 100 cubic centimeters of blood. The blood Wassermann was negative.

At cystoscopy the bladder mucosa was normal. The ureteral orifices were normal in appearance, shape, and position. The right ureter was catheterized to the renal pelvis and a specimen was obtained. The left catheter was obstructed in the lower ureter and no specimen was obtained. The right specimen showed cloudy straw colored urine, containing a few red and white blood cells and some epithelial cells. X-ray examination with the catheters in position showed the right catheter in the renal pelvis at the tip of the third lumbar vertebra. The left was at the sacro-iliac synchondrosis, but no shadow of a calculus was seen (Fig. 4).

A second cystoscopic examination confirmed these findings. A ureteropyelogram was attempted on the left side but no shadow of iodide fluid was seen. Indigocarmine injected intravenously appeared from the right side in 4 minutes, but none appeared from the left side in 15 minutes. The condition was thought to be an advanced left renal tuberculosis and operation was performed.

Fig. 9. Section of nodule in Case 4 showing a matrix of connective tissue with flattened epithelium. Several glomeruli present, overgrown by fibrous tissue. Low power.

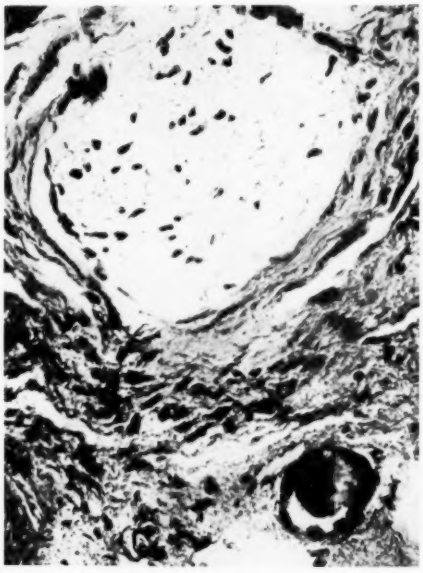

Fig. 10. Photomicrograph from aplastic kidney in Case 5, showing glomerulus and one tubule enclosed in connective tissue. Glomerulus has been invaded with connective tissue which has undergone hyaline degeneration. Lumen of tubule contains an albuminous cast. High power.

On opening the left loin we saw a small mass of tissue in the kidney bed. This consisted of several rounded cyst-like bodies, one the size of a plum, the other much smaller. No ureter could be made out. The pedicle consisting of several small vessels, was ligated and the mass removed. The two cystic masses were connected by fibrous tissue bands (Fig. 5).

Incision of the cysts revealed a more or less viscid fluid, dark amber in color, about 15 cubic centimeters from the larger and 5 cubic centimeters from the smaller. This fluid showed on examination to have approximately the same findings for urea, etc. as for blood. Urea, .360 gms. per liter of fluid; urea nitrogen, 16.80 milligrams per 100 cubic centimeters of fluid; creatinin, 1.59 milligrams per 100 cubic centimeters of fluid; sugar, .093 per cent.

Examination of the tissue removed showed an irregular, dense, fibrous tissue, with areas of hyaline fusion, containing nests of poorly developed tubules, the lining epithelium of which is swollen, so that its differentiation is lost. The lumina are filled with hyaline casts.

Glomeruli are rare and the capillaries in Bowman's capsule are disintegrating. Sections of the cyst wall show it to consist of a thin capsule of fibrous connective tissue having an inner margin of flattened epithelial cells (Fig. 6).

Diagnosis: aplasia of kidney with multiple cyst formation of rudimentary tubules.

Patient has much improved, has gained 40 pounds in weight, and has been free from symptoms since operation.

CASE 4. Mr. D. St. G., age 30, was admitted to the hospital on May 27, 1926, complaining of anuria of 4 days' duration. He had been suffering from slight attacks of pain in both loins for the 2 previous years. These attacks were accompanied by some burning urination. He had a slight attack of pain in the right loin, radiating down to the groin, shortly before the onset of the anuria. The history apart from this was negative.

On admission the patient appeared in evident distress, though there was no vomiting or nausea, and no œdema of face, hands, or feet, and mentally he was quite clear. The tongue was coated and dry. The eye grounds were normal. General examination was negative.

Blood pressure 110–75.

Examination of the genito-urinary system revealed no costolumbar tenderness. The kidneys were not palpable, though there was slight tenderness in the left loin on bimanual palpation of that side. No masses were palpable in the loins. There was no tenderness along the course of either ureter, and no suprapubic distention. The penis was normal in

Fig. 11. Aplastic left kidney and hydro-ureter removed from Case 6, a boy of nine years. Ureter enormously dilated and tortuous with narrow stricture at junction with bladder. Kidney is a shell of connective tissue containing a few glomeruli and rudimentary tubules.

Fig. 12. Photomicrograph of section of tissue from aplastic kidney in Figure 11, showing the hyaline remains of glomeruli, with a few dilated tubules containing casts. There is a generalized round cell infiltration of the connective tissue. Low power.

conformation. No discharge was present. The urethra easily admitted No. 16 soft rubber catheter but no urine was obtained from the bladder. The scrotum and contents were normal. Prostate per rectum appeared normal to the examining finger. X-ray of the kidney and bladder region did not show any shadow, which would suggest a calculus.

The blood urea findings at the time were blood urea, 1.42 grams per liter of blood; blood urea nitrogen, 66.36 milligrams per 100 cubic centimeters of blood.

He was treated symptomatically: heat to the loins, electric baker and intravenous salines of 10 per cent glucose. The following day he had not voided and was cystoscoped. The bladder was symmetrical, the mucosa normal; the ureteral orifices normal in contour and position. The right ureter was catheterized for a distance of about 4 centimeters when definite obstruction was met. The left ureter was catheterized for about 15 centimeters when definite obstruction was met. No specimens of urine were obtained. X-rays taken with catheters in position showed both in the relative positions mentioned, but no shadows were seen suggestive of calculi. No clearly defined kidney shadows were seen. The cystoscopy was repeated the following day but with the same negative results (Fig. 7).

On the morning of May 31, he had still not voided any urine, and it was seen that his condition was critical. He had become nauseated and was vomiting all fluids taken. He had become œdematous and was also somewhat cyanosed and dyspnœic. An operation was indicated as the last possible means of relief, as he had not voided for 7 days.

In view of the history of pain on both sides and the slight tenderness noted on the left side at examination, that side was opened first. His blood urea at this time had risen to blood urea, 2.076 grams per liter of blood; blood urea nitrogen, 97.08 milligrams per 100 cubic centimeters of blood.

The opening of the left loin revealed the tissues markedly œdematous. No perirenal capsule was found and no kidney. In the region where the kidney should be there was a small mass of fat and fibrous tissue containing several rounded masses of firmer tissue. Several small vessels entered this, forming a pedicle. From this mass also a fibrous cord ran downward toward the bladder. This mass of tissue was removed (Fig. 8).

The right loin was then opened and a slightly larger than normal kidney found. The surface appeared slightly granular, and was a darker red than is usually seen. The pelvis and ureter were markedly dilated, and the wall of the ureter much thinned out. An opening was made at the ureteropelvic junction and a large quantity of clear pale urine escaped. A bougie was then passed downward and met with

obstruction in the pelvic portion of the ureter. This was overcome and a No. 12 bougie was passed to the bladder. A tube was then inserted in the opening in the pelvis for drainage.

His condition improved immediately upon the establishment of drainage. A large quantity of urine drained from the loin for 2 weeks, when after the right ureter was dilated to No. 9 F., the patient voided and several days later the wound became dry. The urine passed was pale and of a low specific gravity, 1008–1010. There was some slight infection with colon bacillus, following the operation. The small specimen removed from the right side was examined by Dr. T. R. Waugh of the Pathological Laboratory, and his report is as follows:

"Specimen consists of some fat tissue in which are a few filbert-sized masses of firmer tissue. Section shows irregular masses of fat cells connected by a loose fibrous stroma. In some areas are irregular tubular spaces lined by a regular layer of cuboidal epithelial cells. These large pale cells appear of the embryonic type, the arrangement resembles the anlage of convoluted renal tubules. There are also tufts of cells resembling glomeruli containing red blood cells. There is a dense fibrous tissue stroma surrounding these structures and numerous thick walled vessels are seen. There is no related definite kidney parenchyma, although metanephritic blastoma with tubular and glomerular formations are found (Fig. 9)."

Diagnosis: aplastic kidney; congenital malformation of metanephros.

Patient was seen again in October, 1926, when he had gained in weight and strength. He was free from symptoms, but his urine was still of low specific gravity, and there were scattered pus cells and colon bacilli in the urine. Blood urea, .775 grams per liter of blood; blood urea nitrogen, 35.3 milligrams per 100 cubic centimeters of blood.

When eh was seen again in January, 1927, his urine still contained scattered pus and was of low specific gravity. The phenolsulphonephthalein output was 20 per cent for 2 hours. Blood urea, .660 grams per liter of blood; blood urea nitrogen, 30.8 milligrams per 100 cubic centimeters of blood.

The right ureter easily admitted a No. 6 catheter, and there was no hydronephrosis.

CASE 5. Mrs. E. M., age 40, was admitted to the hospital first in 1914, suffering from incontinence of urine following a birth trauma, which had occurred in 1913. She had complete incontinence of urine. Her general examination was negative, the blood pressure was 146–88.

Cystoscopy showed a small bladder containing about 1 ounce of thick creamy pus. The mucosa was inflamed. There was a large opening toward the right side on the floor, communicating with the vagina.

The left ureteral orifice was normal. This was catheterized and normal urine was obtained. No right ureteral orifice could be demonstrated, and indigocarmine injected intravenously appeared from the left ureter but not from the right side, nor from any portion of the right side of the bladder. A plastic operation was performed. This was successful for some months, but incontinence reappeared.

It was found on the next admission that a small fistula from the bladder communicated with the cervix and a hysterectomy was performed. Examination of the urine from the left kidney showed at this time some evidence of infection. She was admitted to the hospital in 1920, suffering from fever, chills, and pain on the left side and also incontinence of urine. A small vesicovaginal fistula was present.

Cystoscopy and catheterization of the left ureter showed an infected hydronephrosis. X-ray with the catheter in place showed a marked kink in the lower left ureter, with the catheter coiled downward toward the iliac crest, evidently a stricture which has resulted from trauma at the time of the hysterectomy.

She again entered the hospital in 1923 in uræmia, and died shortly after admission.

Examination showed a large distended pyonephritic sac on the left side, with the lower portion of the ureter narrowed and bound down in a mass of scar tissue. Examination of the right kidney showed a small mass of kidney tissue about the size of an almond, covered with a thick fibrous capsule. The pelvis was small but the ureter appeared about the normal size. About 3 or 4 centimeters from the bladder it was completely stenosed and became lost in a mass of scar tissue about the bladder. Microscopically the kidney appeared to be made up of a mass of fibrous tissue with a few small blood vessels showing hyaline degeneration of their walls. An occasional tubule with flattened epithelial lining, and a few glomeruli, which had undergone invasion by fibrous tissue, were seen scattered throughout the fibrous tissue of which this was mainly composed (Fig. 10).

CASE 6. L. M., boy, age 9 years, was admitted to hospital May 5, 1924, complaining of frequency by day of five to six times, and cloudy urine, which had been noted by parents for the past 3 years. He had also suffered from enuresis since childhood. On examination he appeared to be well developed and nothing abnormal was noted. His blood pressure was 108–65. The genito-urinary system on examination showed no costolumbar tenderness, the kidneys were not palpable. There was no ureteral tenderness, and no tenderness nor distention of the bladder. His urine was cloudy amber; specific gravity, 1020; acid; albumin +, no sugar. Microscopically it showed pus, a few red blood cells, and a few cocci. No tubercle bacilli were found in the bladder urine. The phenolphthalein test, 1 cubic centimeter given intramuscularly, showed: first hour, 30 per cent; second hour, .22 per cent; total 52 per cent. X-ray of the kidney and bladder region did not show any shadow suggestive of calculus. Cystoscopy showed a rather tight anterior urethra, a No. F.-18 cystoscope being used. The bladder was symmetrical, the mucosa was slightly inflamed. The right ureteral orifice

was normal. The left ureteral orifice was scarred and gaping. The left ureter could not be catheterized. Normal urine was obtained from the right side (Fig. 11.)

From the age of the boy, and the frequency and condition of the ureteral orifice, a diagnosis of probable tuberculous kidney was made and operation performed. At operation the left kidney was found to be small, scarred, with a slightly distended renal pelvis and a markedly dilated and tortuous ureter filled with purulent material and adherent to the surrounding tissues. The kidney and ureter were removed with difficulty. The kidney was a thinned out fibrous sac surmounting the dilated pelvis and ureter. Microscopically it showed a thin wall made up of fibrous connective tissue, a few small blood vessels and the hyaline remains of many glomeruli. A few tubules were also noted (Fig. 12).

The patient made an uneventful recovery. He has since gained in weight and apart from one attack of hæmaturia 6 months later, from the ulceration about the left ureteral orifice, has been free from symptoms.

An analysis of these six cases might prove of interest. From the point of view of sex the numbers are equal, there being three of each. The ages are 9, 19 31, 31, 33, and 40 years.

The left kidney was involved in 4 out of the 6 cases, and the right in 2 This agrees with the majority of cases reported. Out of a short series of 18 cases collected by Goldstein, the left side was involved in 13, the right in 5 cases.

The symptoms which compelled these patients to seek advice, were usually on the side of the remaining kidney, although three of these had definite pain on the side of the aplastic kidney, and in Case 2, the pain was confined solely to that side. The frequency, burning, and pyuria were, in all but one case, due to infection of the solitary kidney.

In Case 6, the symptoms were evidently due to infection of the large distended ureter on the side of the aplasia.

In Case 1, the solitary kidney was the seat of an acute pyelonephritis, and there was a history of an attack of pyelitis 3 years previously during pregnancy. The kidney in the case was about twice normal size, as shown by X-ray examination and at operation.

In Case 2, the remaining kidney was the seat of a low grade chronic pyelitis, as shown by a few white cells at cystoscopy, and a positive culture of bacillus coli communis. No enlargement of this kidney was shown by X-ray examination.

In Case 3, the patient had suffered from attacks by pyelitis on several occasions. The kidney shadow was not shown to be enlarged by X-ray examination.

In Case 4, there was a period of anuria of 7 days, and at operation a slightly enlarged kidney with a dilated pelvis and ureter were found. There was a stricture of the ureter present in its lower third. A similar case was reported by Eisendrath several years ago.

In Case 5, the renal aplasia was considered during the examination for the relief of vesicovaginal fistula and verified at autopsy. The remaining kidney was the seat of infection, and following the trauma to the ureter and the resulting stricture, a large pyonephrosis developed.

In Case 6, the remaining kidney appeared normal in size and function.

There were no associated genital abnormalities in any of these cases.

The bladder was symmetrical in 5 cases. Case 1 showed an absence of the left ureteral orifice and the left half of the trigonal ridge.

The bladder was inflamed in 4 of the 6 cases, which could be explained by the acute infection above.

The right ureteral orifice was not seen in Case 5. Whether this was damaged at the time the vesicovaginal fistula was incurred is a question. A stricture of the lower ureter was present in that case, and the terminal inch or so was lost in a mass of scar tissue.

The ureteral orifices in the remaining cases were in the normal situation.

In Case 6, the left orifice was scarred and gaping, evidently an inflammatory lesion.

The ureter in these cases on the side of the aplasia varied.

In Case 1, there was no evidence of ureteral orifice in any region of the bladder, urethra, or vagina.

It is reasonable to suppose that the ureter and kidney are completely absent, though Lyons reports a case in which a short rudimentary ureter was attached to the bladder in the normal position, though there was no ureteral orifice present.

In Cases 2, 3, and 4, there was a short rudimentary ureter present, which was patent for some distance. In two cases it ended blindly,

but in the third it was continued as a fibrous cord attached to the aplastic kidney tissue, found in that region. In Cases 5 and 6, there was a ureter present throughout, dilated, thickened, and filled with purulent material, each strictured in its lower portion.

A small renal pelvis was found in these two cases, with thickened fibrous walls. No pelvis was found in Cases 2, 3, or 4.

Evidences of renal tissue were found in 5 of these cases. There is no reason to expect any evident traces of renal tissue in Case 1. Many similar cases have been reported (7, 10, 11).

In each of Cases 2, 3, and 4, there was found a small mass of fat and connective tissue, containing nodules of firmer tissue, and in two, small thin-walled cysts. These nodules and cysts were connected by bands of fibrous tissue. They were supplied by one or more small blood vessels, and in one the fibrous cord passed downward to become attached to the lower and patent portion of the ureter. Section of the nodules of tissue showed a predominating connective tissue matrix, containing nests of cells, epithelioid in character, in many instances forming ducts, the lumina of some containing albuminous material resembling casts. In other portions rudimentary glomeruli could be made out. These were as a rule very few, and many were replaced by fibrous connective tissue, which in places showed hyaline degeneration. The cyst wall was lined by flattened epithelium and made up of connective tissue fibers. The cyst in Case 3 contained urea, creatinin, and sugar in the proportion similar to that found in blood.

In Cases 5 and 6, there was found a definite pelvis surrounded by a shell of tissue composed of connective tissue, tubules, and a few glomeruli, many of which had been replaced by fibrous tissue. Whether these two cases are aplastic in origin or whether they are the result of secondary atrophy is a question not easy to answer. A case similar to Case 6 has been reported by Krotoszyner.

The differentiation between renal aplasia and secondary atrophy is difficult to make histologically. Kaufmann's *Pathology* states: "there is no essential difference in the histological picture." Oertel is of the opinion that in a secondary atrophied kidney, there is usually some evidence of a ureter and a pelvis being present.

In all probability Cases 5 and 6 might fall into the class of atrophic cases; but whether the atrophic process commenced in a kidney which was normal or in one that was hypoplastic in nature is impossible to say.

Hinman's work as well as that of Barney and of Scott tend to show that ligation of the ureter causes a hydronephrosis rather than an atrophy, so that one may assume that these two latter cases are congenital in origin.

CONCLUSIONS

The conclusions to be drawn from this series of cases may be summarized as follows:

1. Unilateral renal aplasia is not uncommonly seen in urological practice.
2. The lesion appears to be more common on the left side than on the right.
3. There is usually a lesion of the opposite or remaining kidney.
4. There is sometimes unexplained pain on the side of the aplasia.
5. The operation and removal of the rudimentary kidney relieved the pain in 2 cases for some unexplained reason.
6. In some cases nodules or cysts containing renal tissue are found, without pelvis or ureter formation.
7. The aplastic kidneys in this series were all functionless.

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CARCINOMA OF THE ŒSOPHAGUS

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THE œsophagus is a musculomembranous tube, about 25 centimeters (10 inches) in length connecting the pharynx and the stomach, beginning at the lower border of the cricoid cartilage, between the sixth and seventh cervical vertebræ, about 15 centimeters from the incisor teeth, and ending below the diaphragm, opposite the tenth (sometimes the eleventh) thoracic vertebra. The subdiaphragmatic part is about 3 centimeters long. Four areas of constriction are commonly agreed upon, although others have been described. Of these, one is at the very beginning, a second at the passage through the diaphragm, a third at the point where the arch of the aorta crosses the œsophagus, and the fourth where the latter passes behind the origin of the left bronchus. They all seem to be closely related to the positions at which cancers occur, as will be shown later.

The lymphatics of the œsophagus, which are of special importance in the explanation and understanding of metastasis of œsophageal cancers, are arranged in two networks, one of which is submucous, the other is in the muscular coat. The stems which drain the networks of the cervical portion of the œsophagus pass to the superior deep cervical and retropharyngeal nodes, those draining the thoracic portions of the network to the posterior mediastinal nodes, and those originating in the networks of the terminal portion pass to the nodes of the cœliac group. From these three groups of nodes there is hardly any limit to the anastamoses of lymphatics in the neck, chest, and abdomen, a fact which can readily explain some of the extensive metastases of cancers of the œsophagus. The extensive submucous network of lymphatics will explain in most instances why local lesions may become so large before more distant metastasis occurs. The close proximity of the trachea and bronchi and of their lymph nodes to the œsophagus and to the œsophageal nodes, as shown in the photograph, will explain why they so readily become involved particularly in growths situated in the middle third (Piersol's *Anatomy*).

For convenience the œsophagus is frequently divided into thirds. The upper third extends from the cricoid cartilage to the point where the aorta crosses the trachea and œsophagus. The middle extends from this point to 4 centimeters below the bifurcation of trachea or about the level of the lower edge of the fifth thoracic vertebra, and the lower extends from this point to its junction with the stomach opposite the tenth thoracic vertebra. The bifurcation of the trachea occurs about the middle of the œsophagus.

Analyzing 5,900 autopsies performed in the past 5 years at the Philadelphia General Hospital, we found 812 cases of malignancy. Of these, 41 (5.05 per cent) died of cancer of the œsophagus. Of these 41 cases, 39 (95 per cent) were men; 8 occurred in the colored race. The oldest patient was 97 and died of cerebral hæmorrhage. The cancer in this case was small and had not given rise to any complaints nor were there any metastases. The youngest patient was 41 and gave symptoms of increasing difficulty in swallowing for 24 months, which was the longest duration of symptoms of any of the cases. He had a grade 3 (Broder's) prickle cell carcinoma involving the upper part of the lower third of the œsophagus for a length of 3 centimeters and at time of death it only partially obstructed the lumen of the organ. There was no distant metastasis of the growth, but the local extension was of a fairly marked degree involving the trachea, mediastinal lymph glands, and surrounding tissues.

Of the 41 patients, the average age at death was 60 years and 6 months, and the great majority were in their sixties.

SYMPTOMS AND DURATION OF LIFE

Difficulty in swallowing was by far the commonest symptom. It occurred in 29 cases and

was one of the first symptoms in 22, occurring very late in 7, and was the only symptom for a long time in 15.

Weakness and loss of weight were early and constant symptoms. They were the first symptoms in many cases and with the exception of one case were practically always present. This patient was a white man 72 years old, and did not have any symptoms until 2 months before death, at which time he developed a cough with expectoration of bloody sputum. Four days before death, for the first time he developed difficulty in swallowing. At autopsy he was found to have a grade 3 prickle cell carcinoma of the œsophagus 3 centimeters below the cricoid cartilage. The growth was flat and encircled the œsophagus for the length of 2½ centimeters. It had perforated into the trachea at this position and had given rise to a large superior mediastinal abscess, but the lumen of the œsophagus was only partially obstructed. The patient died of deglutition pneumonia.

Pain and vomiting were comparatively infrequent symptoms. Epigastric pain, mostly of a mild degree, was present in 7 cases; of these 7, 5 showed the growth to be in the lower third of the œsophagus and in each instance to extend into the stomach. In the other 2 cases the growths were present in the middle third, but one of them had given rise to metastasis to the liver, cœliac glands, and most of the abdominal organs. The other practically occluded the lumen for 5 centimeters but had not given rise to any local extension or metastasis. Only one patient complained of actual pain on swallowing. This pain was of a very severe degree and of a burning character occurring 2 months before death, and preceded by 3 months of difficulty in swallowing. The case showed an ulcerative hæmorrhagic carcinoma involving the upper part of the lower third for 4 centimeters. The posterior mediastinal glands were slightly involved and there was a very large gland along the lesser curvature of the stomach. The involvement of the structures in this case was not different from many others who did not have pain and we were unable to determine its cause. Pleural pain occurred in 6 cases. In each the perioesophageal tissues and structures were involved in various degrees and pleural adhesions were present.

Vomiting was the earliest sign in 3 cases. Two of these were accompanied by nausea, and metastatic ulcerative areas were found in the stomach. Regurgitation occurred in many cases and in each there was more or less obstruction.

Cough was a prominent symptom in 10 cases. In these the trachea, bronchi, or lungs were involved, or pressed upon with the exception of one where a metastatic mass surrounded the aorta and involved the recurrent laryngeal nerve. In 4 cases the trachea or left bronchus was perforated. There were 2 examples of each.

Spitting of blood occurred in 11 cases, in 6 cases from the metastases to the trachea, bronchi, or lungs; in 2 from ulcerative metastatic lesions in the stomach, and in 3 from the œsophageal lesions.

Hoarseness was present in 5 cases. Early symptoms, as given in textbooks, such as substernal pressure, or discomfort, or spasm of the cardiac end of the stomach were not mentioned.

Symptoms lasted as long as 24, 22, 17, and 15 months; the shortest duration varying from none at all to 2 or 3 weeks. Three gave no symptoms referable to the œsophagus at all; in one the lesion was small; in another the lesion involved the middle third for 8 centimeters and had metastasized to the peribronchial and pancreatic lymph glands. The patient was in a moribund condition on admission and the history obtained from relatives, who may well have been inaccurate. The third case was a well nourished white man, 72 years of age; his history was also given by relatives. The œsophageal lesion was small and flat, arising in the upper part of the lower third of the organ and metastasizing widely throughout the chest and abdomen. A few cases had symptoms referable to the œsophagus for 1 to 3 weeks. For the most part, these growths were flat and produced very little obstruction, but were not very different in local character or extent of metastasis from those giving rise to long standing symptoms.

Some of the lesions causing complaints for the longest periods of time, peculiarly, were

not as extensive locally, nor did they metastasize as widely as many of the others. The average duration of symptoms of the entire group was about 7 months. In most of the cases, wherever possible and indicated, a gastrostomy was performed; but seemed to have little or no effect in prolonging life, except in cases of obstruction. Twenty-two died of bronchopneumonia; 3 of empyema; 5 of lung or mediastinal abscesses; 1 of pulmonary hæmorrhage, and 1 of gastric hæmorrhage. The others died of starvation or from metastases of the cancer.

PATHOLOGY

The description of three cases, which exhibit important differences in the extent of the local lesions and metastases, are first given.

CASE 1. Shows an extensive local lesion without any metastasis.

A Chinese, male, aged 48 years, was admitted to the hospital May 14, 1925, and died of a terminal bronchopneumonia September 13, 1925. He complained of difficulty in swallowing and weakness for 7 months before death; had lost a great deal of weight, and for the past 3 months had vomited frequently, but had not complained of any pain or other important symptoms.

At autopsy (P.G.H. No. 10,102) the upper part of the œsophagus was deeply injected. The entire middle third was the seat of a necrotic ulcer which extended entirely through the wall of the œsophagus so that the upper and lower thirds were barely continuous. The upper margin of the ulcer was thickened and sharply demarcated from the œsophageal mucosa. The lower margin was similar except a narrow band-like process of the growth extended down the œsophagus through its lower third into the cardiac end of the stomach where it spread out into an oval shaped ulcer, the size of a dollar. The ulcer of the stomach involved the whole thickness of the mucosa, its edges being raised and rolled, but not indurated. Sections at various levels showed it to consist of a soft, pearly-white, friable, and mushy tissue. The nearby lymph nodes were not enlarged and there were no metastases. The lungs were the seat of a fairly marked tuberculosis and bronchopneumonia.

Microscopic study revealed a typical prickle-cell carcinoma. Broder's classification grade 1 to 2.

CASE 2. Adenocarcinoma of the upper third of the œsophagus with extensive metastasis above the diaphragm.

A white man, aged 62 years, was admitted June 5, 1922, and died of a terminal bronchopneumonia June 9, 1922. He was always in good health until a year before death, when he began to lose weight and strength. He developed difficulty in swallowing 2 months, pain in the right side of his chest 2 weeks, and loss of voice 3 days before death.

At autopsy (P.G.H. No. 5,444) a tumor was found adherent to the under surface of the sternum at the level of the first and second ribs. The mass sprang from the superior and anterior mediastinum and a number of tumors of bean size were adherent to the posterior surface of the sternum. In the superior and anterior mediastinum the tumor was the size of one's fist. It was of a firm consistency and pale yellow in color, pressing upon the upper part of the ascending aorta, involving the outer wall of the trachea and appearing to have sprung from the upper part of the œsophagus. When the œsophagus was opened, a large, firm, fungoid mass was found in its upper third, arising from its posterior wall and almost completely occluding its lumen for a length of 7 centimeters. The tumor was nowhere circumscribed and had a pale gray yellow color. The rest of the œsophagus and stomach did not show any important gross changes, but peribronchial and mediastinal glands were much enlarged and replaced by the tumor tissue.

The lungs were firmly adherent to the posterior thoracic wall, their surfaces being very nodular due to projecting pale white tumor masses. Scattered diffusely throughout each lung were circumscribed firm white tumor masses, ranging from 5 millimeters to 5 centimeters in diameter. There were nodules on the pleural surface of the diaphragm, but there was no evidence of metastasis to the abdominal organs. Microscopically the tumor stroma consisted of delicate fibrous tissues, in the meshes of which were very large clumps of epithelial cells, with some adenomatous arrangement and which showed considerable variations in staining qualities. The cells for the most part were rounded and varied very slightly in size. There was no mucous formation in the growth.

Diagnosis: medullary adenocarcinoma.

CASE 3. Squamous cell carcinoma of the lower third of the œsophagus with extensive metastasis above and below the diaphragm and to the upper portion of the right humerus.

A colored man aged 49 years, 8 months before death, began to complain of weak spells and pain in the epigastrium. This pain was irregular in its occurrence and was severe enough to keep him awake at night, but was relieved by sodium bicarbonate until the past 2 or 3 months. He was nauseated frequently, but did not vomit. He also had complained of severe aching pain in his right shoulder for two months.

X-ray showed obstruction ot the œsophagus at the eighth thoracic vertebra and a neoplastic growth which had destroyed the neck of the humerus. The Wassermann test was negative.

At autopsy (P.G.H. No. 6,942) the œsophagus was found to be the seat of a large ulcerative mass involving its lower portion for a distance of 5 centimeters. The process had not extended through the wall of the organ, but had extended into the cardiac

end of the stomach giving rise to an ulcer 2 centimeters in diameter. The edges of the ulcer in the stomach were raised and indurated, and its base presented an irregular and indurated surface. The œsophagus above the ulcerating mass presented several firm and small elevated areas beneath and covered by the mucosa. These areas extended through the middle third and on section were of the same character as the mass below. At the bifurcation of the trachea the lymph nodes were enlarged and were replaced by tumor tissue. The œsophagus was adherent to the trachea just above its bifurcation and at this position the growth had infiltrated into the mucosa of the latter, but had not perforated through.

Similar tumor nodules as large as 1 centimeter in diameter were scattered throughout both lungs. The lymph glands at the hila were involved. Both adrenals were replaced by the tumor, and both kidneys contained numerous hard white nodules, ½ to 2 centimeters in diameter. The liver was studded with tumor nodules and the mesenteric lymph nodes were matted together and replaced by the tumor tissue. The neck of the humerus was destroyed by a similar tumor growth. Microscopic sections showed the tumor tissue in each of these organs to be a typical prickle cell carcinoma. Broder's classification grade 4.

THE EXTENT AND DIRECTION OF THE METASTASES ACCORDING TO THE POSITION OF THE LESIONS IN THE ŒSOPHAGUS

The middle third was most frequently the seat of the primary lesion and the center of the lesion was most commonly above the area of constriction where the œsophagus is crossed by the left bronchus. In the lower third the lesions appeared to have originated usually about the area of constriction where the œsophagus passes through the diaphragm. We could not be sure in the larger local growths that these two areas of constriction were the points where the growths began. In many of the smaller lesions we could be more positive that they did begin at the areas of normal anatomical constriction. (Table I.)

TABLE I.—SITES OF THE ŒSOPHAGEAL CANCERS

	Cases
Upper third	4
Middle third	19
Middle and lower thirds	4
Lower third	14

Upper third. Of the four growths occurring in the upper third, one involved the œsophagus for a length of 5 centimeters and gave rise to no metastases. The cancer was of the prickle cell variety, grade 2, and the patient's symptoms were of only 6 weeks' duration. He died following a gastrostomy.

The three other growths gave rise to extensive metastases in the chest, similar to but not so marked as the second case described in the preceding pages. Two of these lesions perforated into the trachea and in only one did metastases occur below the diaphragm, and this was only one small nodule in the liver. In the cases that metastasized, the lymph glands of the neck and superior mediastinal glands were more extensively involved than the posterior mediastinal glands. (Table II.)

Middle third. Of the nineteen cancers occurring in the middle third, six did not give rise to any metastases. In five of the remaining cases there were no metastases below the diaphragm, while in three of these the metastases were extensive above the diaphragm. There were no cases that metastasized below the diaphragm that did not also metastasize above it, which will be seen to be different from the lower third growths.

Eight of the middle third cancers gave rise to extensive metastases above the diaphragm, two of which also extended to the abdominal organs, involving the liver, most of the lymph glands, both kidneys, and adrenals. In one of the eight, the only metastasis below the diaphragm was a small nodule in the right kidney; another showed the only metastasis below the diaphragm to be in the scrotum and to involve the testicle. The other cases in which metastases occurred below the diaphragm only the lymph glands at the fundus or along the lesser curvature of the stomach were involved.

The posterior mediastinal glands and peribronchial glands which are shown in the photograph were the first to become involved and when any metastases occurred they were always involved. Many cases showed them to be involved, when no other structures were and their close proximity to the growth is very evidently the explanation. (Table III.)

Middle and lower thirds. These four cancers involved the middle and lower thirds to such an extent that we were unable to determine in which of them the growth started. With the exception of one, they metastasized widely

TABLE II.—CANCERS OF UPPER THIRD

Sex Age	Symptoms	Type of cancer	Extent of local lesion	Metastasis	
				Above diaphragm	Below diaphragm
M. 62 5444	Loss of weight and strength 1 yr. Difficult swallowing 2 mo. Pain in chest 2 wk.	Adenocarcinoma, medullary type	Fungoid mass 7 cm. length, almost occludes the lumen	Extensive Anterior, superior and posterior mediastina. Both lungs	None.
M. 52 6210	Cough and spitting blood 4 mo. Difficult swallowing 2 mo.	Squamous cell grade 3 to 4	Mass 1¼ cm. partially obstructing œsophagus and perforating into trachea	Marked Cervical and superior and posterior mediastinal nodes. Trachea. Pleural surface of lungs	A single small nodule in liver.
M. 73 9023	Cough 6 wk. Lump in throat 5 wk. Spat up blood 5 wk.	Prickle cell grade 2	A flat ulcerative lesion 5 cm. in length. Center necrotic and hæmorrhagic. Very slight obstruction	Nodules in submucosa beyond mucous edge	None.
M. 72 16745	Cough and bloody expectoration 2 mo. Difficult swallowing 4 days	Prickle cell grade 3	Flat ulcerative lesion 2.5 by 3 cm. perforating into trachea. Very slight obstruction in œsophagus	Extensive Large mass in superior mediastinum involving trachea and large vessels. Posterior mediastinal nodes	None.

above the diaphragm and in two instances both lungs were studded with cancerous nodules. Two of them gave rise to extensive metastases below the diaphragm, and involved the liver, kidneys, adrenals, and lymph glands.

In the other two the metastases below the diaphragm were present only in the glands at the fundus of the stomach and along the lesser curvature.

One of the four cases metastasized to the cœliac glands without any metastases above the diaphragm. (Table IV.)

Lower third. Of the fourteen cancers involving this portion of the œsophagus there were three which did not metastasize. One metastasized extensively above without any below the diaphragm.

In 9 cases metastases occurred below the diaphragm and in 2 there were no metastases above. Five of the 9 extended extensively throughout most of the abdominal organs and 3 of them also metastasized to a fairly marked degree above the diaphragm.

The lower third cancers therefore gave rise to the highest number of extensive metastases below the diaphragm. Of the cancers that metastasized there was only one which did not involve the abdominal organs. This is because of the close communication between the lymphatics of the lower third of the œsophagus and the cœliac nodes of the abdomen.

THE RELATION OF THE DEGREE OF MALIGNANCY TO THE EXTENT OF METASTASES AND DURATION OF LIFE AFTER ONSET OF SYMPTOMS

In one instance the cancer was of the adenomatous type arising from the mucous glands in the submucosa, 1 was of the basal cell type, and 39 were squamous cell cancers. Twenty-eight of the squamous cell cancers were of the prickle cell variety, while in the remaining 10 there was less differentiation.

In this classification we have used Broder's grading. We believe that there is a great deal of personal variation in the use of this method, but that with experience one can in the majority of instances agree with his fellow pathologists.

In cases on which we differed the degree was slight and the average should be fairly accurate. The Broder's grade was determined while we were still in ignorance of the clinical course and metastasis.

Grade 4,–9 cases. The average duration of life after the onset of the first symptoms was 3½ months and all of the cancers gave rise to extensive metastases either above or below the diaphragm or both. In 5 of the 9 the metastases were extensive above and below. Three of these occurred in the middle third, and 2 in the lower. In 2 cancers of the lower third, metastases occurred extensively below the diaphragm and slightly above it.

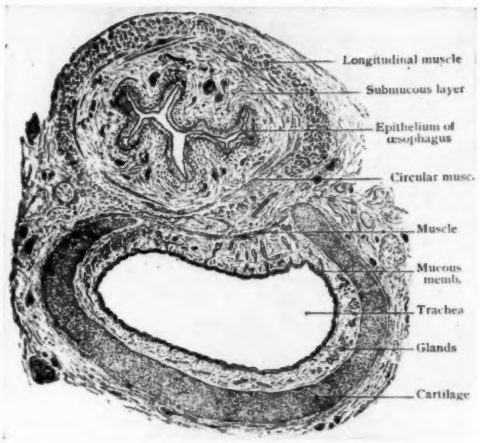

Fig. 1. Transverse section of trachea and œsophagus of child, seen from below. (From Piersol's *Anatomy*.)

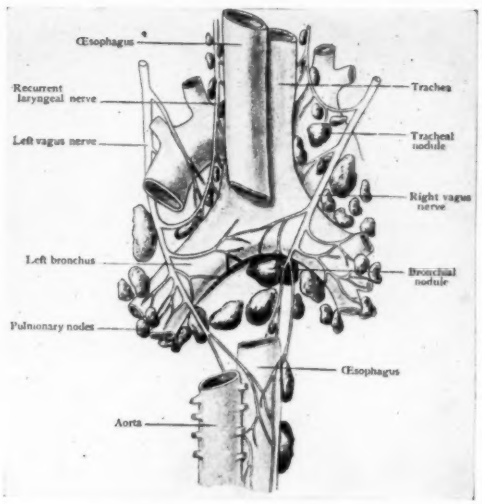

Fig. 2. Tracheal and bronchial lymph nodes, viewed from behind. (From Piersol's *Anatomy*.)

In 2 other cases the metastases were extensive above and slight below. One occurred in the upper third and the other in the middle.

Grade 3,–12 cases. The average duration of life after the first onset of symptoms was 5 months. Extensive metastases occurred in 5 cases, moderate metastases in 2, slight metastases in 3, and no metastases occurred in 2 cases. Of the cases, of this group that did not give rise to any metastases, one did not have any complaints referable to his œsophagus and the growth was small. The other case had symptoms for only 3½ months and the local lesion involved the œsophagus for 7 centimeters. We were in doubt on microscopic study whether we should have called this a grade 2 or 3 prickle cell cancer. Of the cases where only a slight metastasis occurred one had given rise to symptoms 5 months, another 4 months, and the third had not given rise to any symptoms, and in 2 of them the local lesions were small.

Of the cases in which metastases were moderate, one gave symptoms 3 months and the other 4 months. The first cancer locally was small but the second involved the œsophagus for 10 centimeters.

Grade 2,–15 cases. The average duration of life after the onset of symptoms was 8 months and 7 days. Extensive metastases occurred in 5; moderate metastases occurred in 4; slight in 1, and no metastases in 5. Of the cases giving rise to extensive metastases the shortest duration of symptoms was 6 months and the longest duration of symptoms was 10 months. The average duration was about 8 months. In all of the cases the local growths were large and involved the œsophagus for an average length of 12 centimeters.

Where the metastases were moderate, the longest duration of symptoms was 22 months and the shortest was 4½ months. The local growths were large and involved the œsophagus for an average length of 8 centimeters. The case which had only very slight metastases in the immediate œsophageal lymph glands had complained for 11½ months and the local lesion was 4½ centimeters long. The shortest duration of symptoms in the cases in which no metastases occurred, was 1½ months; the longest was 15 months and the average was 7 months. The local lesions in these cases were smaller than the others but averaged 6 centimeters in length, the largest being 10 centimeters.

Grade 1,–3 cases. There were only 3 cases of this type and the average duration of life was 16 months. One of these had had

TABLE III.—CANCERS OF MIDDLE THIRD

Sex	Age	Symptoms	Type of cancer	Extent of local lesion	Metastasis	
					Above diaphragm	Below diaphragm
M. 6736	97	Died of cerebral hæmorrhage. No history referable to the œsophagus	Prickle cell grade 3	Small ulcerative non-obstructive lesion 2 cm. Lower end of middle third	Surrounding tissues were adherent but no evidence of metastasis	None.
M. 7029	55	Cough, expectoration, loss of weight 6 mo. Hoarseness 6 wk.	Squamous cell grade 3	Flat ulcerative lesion 7½ by 5 cm. Very little obstruction	Local extension around trachea and œsophagus	Small nodule in right kidney.
M. 7105	83	Attacks of severe epigastric pain 10 mo. No dyspepsia	Prickle cell grade 2	Ulcerative lesion 5 cm. Marked obstruction each end and dilated in the center	None	None.
M. 7257	50	Loss of weight and soreness in right chest 6 mo. Profuse pulmonary hæmorrhage 4 mo.	Prickle cell grade 2	Flat ulcerative lesion 10 cm. in length continuous with mass in chest	Extensive Large mass in post mediastinum, perforating into left bronchus and extending into each lung at the hila	None.
F. 7523	60	Difficult swallowing and loss of weight 12 wk. Cough and vomiting 8 wk.	Prickle cell grade 3	Obstructive growth 5 cm. in length, beginning at bifurcation of trachea	Marked Invasion into wall of left bronchus and showing on mucosa. Mass at hila of lungs	Two lymph nodes just below diaphragm at cardiac end of stomach.
F. 8034	48	Cough and difficult swallowing 10 wk.	Prickle cell grade 3	Fungoid and degenerative growth 9 cm. in length, causing obstruction	Mass size of lemon around aorta and trachea. Pleura and mediastinal nodes	Cœliac nodes. Mass size of an English walnut pressing on duodenum.
M. 8212	65	Increasing difficult swallowing 22 mo.	Prickle cell grade 2	Obstructing mass 9 cm. in length. Perforating 5 cm. below arch of aorta	Tissues immediately surrounding perforated area. Slight extent	None.
M. 8248	60	Increasing difficult swallowing 4 mo.	Squamous cell grade 3	Ulcerating and constricting area ½ by ¾ cm. Small perforation into pleural cavity	Perforation giving rise to empyema. No metastasis	None.
M. 8463	63	Difficult swallowing 10 mo. Pain in right chest 2 mo. Cough and bloody sputum 3 wk.	Prickle cell grade 2	Ulcerative and obstructive lesion for 9 cm.	Extensive Large mass surrounding trachea and bronchi and hila of lungs. Nodes throughout both lungs	None.
M. 9184	60	Difficult swallowing 7½ mo. Difficult breathing 4 wk.	Basal cell	Obstructing mass 8 cm. in length	None	None.
M. 9199	64	Difficult swallowing 3 mo. Pernicious anæmia 5½ yr.	Squamous cell grade 3	Obstructing and ulcerative necrotic growth 4 by 4 cm.	Posterior. Mediastinal nodes. Nodes at bifurcation of trachea	Several, 7–8, nodules 2 by 2 cm. in liver.
M. 9625	65	Inability to swallow solids 4 mo.	Prickle cell grade 3	Obstructive and ulcerative lesion 3 cm. incideling argon.	Mass surrounding trachea and aorta. Hilum right lung	Cœliac nodes to slight degree scrotum.
M. 9715	68	Increasing difficulty in swallowing 5 mo. Frequent regurgitation 2 mo.	Squamous cell grade 4	Obstructive ulcerative and fungating growth 10 cm. in length. Lack of continuity between upper and lower ends	Extensive Surrounding tissues in posterior mediastinum. Both lungs studded throughout. Lt. bronchus filled with the tumor	Liver studded. Both adrenals one nodule in left kidney, pancreas 5th rib. No metas. in abdominal lymph glands.
M. 10,102	48	Difficult swallowing 8 mo. Vomiting frequent	Prickle cell grade 1 to 2	Flat ulcerating lesion of whole middle ⅓ with a narrow band extending into the stomach	None	Oval shape cancerous ulcer, size of a dollar in cardiac end of stomach.
M. 10,111	50	No history referable to œsophagus	Prickle cell grade 3–4	Flat ulcerative lesion 7 cm. in length	Peribronchial glands	Peripancreatic glands.
M. 10,180	61	Difficult swallowing 11½ mo.	Prickle cell grade 2	Crater-like ulceration 4½ cm. Very little obstruction	Peribronchial glands	None.

TABLE III.—CANCERS OF MIDDLE THIRD—*Continued*

Sex Age	Symptoms	Type of cancer	Extent of local lesion	Metastasis	
				Above diaphragm	Below diaphragm
M. 43 10,385	Increasing difficulty in swallowing 17 mo. Gastrostomy 15 mo.	Prickle cell grade 2	Obstructing growth 5 cm. by 4 cm. wide. Perforated at its center	Necrotic ulceration in left bronchus. No cancer found in this tissue	None.
M. 67 16,854	Difficult swallowing 3 mo. 2 wk. before admission	Prickle cell grade 1–2	Partial obstructing fungating and ulcerating mass 5 cm. in length	None	None.
M. 54 9592	Pain in epigastrium 3½ mo. Difficult swallowing and vomiting 1 mo.	Prickle cell grade 3	Mass at upper part of middle third involving entire thickness of œsophagus. Serosa not broken	Postmediastinum nodules scattered through both lungs	Liver studded. Largest mass 10 cm. Both kidneys contain numerous nodules. Mesenteric and cœliac lymph glands.

symptoms for 24 months and the growth had given rise to extensive metastases in the chest and to a few lymph nodes of the cœliac chain. The other 2 had caused symptoms for 17 and 7½ months respectively and the local lesions were large, but had not given rise to any metastases.

Only one tumor was of the basal cell character and involved the middle third for 8 centimeters but had not caused any metastases. Case 2 described in detail in the preceding pages was a very malignant adenocarcinoma.

SUMMARY

Of the 41 cases of œsophageal carcinoma comprising this study, metastases occurred below the diaphragm in 22. In 9 of these the metastases were extensive, in 11 metastases occurred in the liver, in 8 only the glands at the fundus of the stomach and the cœliac chain were involved. There were 4 instances in which the metastasis occurred below the diaphragm without any above it, and all of the primary growths were fairly large, involving only the lower third of the œsophagus. In one, metastasis occurred in the liver, kidneys, adrenals, and lymph glands; in the others it was limited to the cœliac and mesenteric lymph glands. Metastasis limited above the diaphragm was present in 9 cases and in 4 instances it was extensive. There were 18 cases in which the metastasis occurred both above and below.

Ten of the cancers, or about 25 per cent, did not show any metastasis, but one, however, had perforated and had given rise to an empyema. Two of them were prickle cell cancers, grade 1; 5, grade 2; 2, grade 3; and 1 was a basal cell cancer.

As brought out in the preceding pages, the cancers of the higher grades that did not give rise to metastases were of a short duration.

DISCUSSION

Dr. Chevalier Jackson in a paper on "Why Can Surgeons Not Cure Cancer of the Œsophagus?"[1] brought out many interesting points in which he rightfully condemned many of the procedures in the diagnosis of cancer mentioned in surgical textbooks. He states that the œsophagescope and X-ray are the only two methods of procedure to be used, and that the lesion can readily be diagnosed with the œsophagescope when it is no larger than an orange seed.

The greatest difficulty with early diagnosis of cancer does unfortunately not depend on our present day methods of procedure, but upon the fact that cancers of the œsophagus do not cause recognizable symptoms until very late.

The œsophagus does not have very sensory nerves, for which reason the earliest symptoms are reflex. Substernal discomfort or spasm of the cardiac end of the stomach are two early symptoms in some cases. Most commonly difficulty in swallowing causes the patient to apply for treatment and, usually, by the time this symptom occurs, the lesion is fairly extensive and may or may not have metastasized, depending upon the degree of

[1] Arch. Surg., 1926, xii, 236.

TABLE IV.—CANCERS OF MIDDLE AND LOWER THIRDS

Sex	Age	Symptoms	Type of cancer	Extent of local lesion	Metastasis	
					Above diaphragm	Below diaphragm
M. 7045	50	Belching 7 mo. Difficult swallowing 3 mo.	Prickle cell grade 2	Ulcerative lesion of lower 15 cm. Destroying entire wall. Very slight lessening of lumen	Mass involving the trachea. Posterior mediastinal nodes. Hilum left lung	Lymph nodes along lesser curvature of stomach.
M. 7074	43	Difficult swallowing a few (?) months	Prickle cell grade 2	Ulcerating and ¾ obstructing lumen for 13 cm. Extending within 3 cm. of stomach	Infiltrating into posterior mediastinum and hilum of left lung. Outer wall of pericardium	Mass 7 cm. infiltrating pyloric region of stomach. Glands along lesser and greater curvatures of stomach.
M. 7281	67	Difficulty in swallowing and sore throat 4 mo.	Prickle cell grade 2	Ulcerating lesion from bifurcation of trachea to within 2 cm. of stomach. Partial obstruction	None	Mass 6 cm. in cardiac end of stomach extending from lymph glands at fundus.
M. 8253	75	No history referable to œsophagus. From nervous ward	Squamous cell grade 3 to 4	An ulcerative lesion at junction of middle and lower thirds	Peribronchial glands. Numerous nodules throughout both lungs. Mass size of a hen's egg at hila of lungs	Cœliac glands. Liver studded largest mass 6 cm. Left adrenal. Left kidney.

malignancy of the individual growth. The œsophagus is an easily dilatable tube and a fairly large growth may permit the food to pass without causing any complaints, for the growths most commonly are of the flat ulcerative type. Most commonly the patient does not seek advice until the growth has increased to such a size that it produces some difficulty in swallowing, and, in many of our cases, the patients had lost a great deal of weight and already had widespread metastases before any signs referable to their œsophagi occurred.

For the above reasons a physician should not make a diagnosis of gastric neurosis, nervous spasm of the cardia of the stomach and so forth, without first having ruled out cancer of the œsophagus, especially if the patient is any way close to the cancer age. Any indefinite complaints in the chest or upper abdomen should cause one to search for cancer of the œsophagus.

CONCLUSIONS

Cancer of the œsophagus forms a little more than 5 per cent of all cancers. It is a lesion that occurs for the most part in males. In this series of 41 cases, 39 (95.15 per cent) were men. It occurs most commonly in late life, and the average age in our series was 60½ years.

Symptoms occur very late, the average duration of life after the onset of the first symptoms being about 7 months. The most common symptom causing the patient to seek medical aid is difficulty in swallowing, while dysphagia in its true meaning, painful swallowing, is very common.

About 75 per cent of cancers of the œsophagus metastasize, and the cause of death most commonly is an intercurrent bronchopneumonia. The lesion occurs most commonly at the level of the bifurcation of the trachea at the point where the œsophagus is crossed by the left bronchus (18 of this series). The second most frequent position is about the point where the œsophagus passes through the diaphragm (13 of this series). These are the points where normal anatomical constrictions of the œsophagus are most marked except at its very beginning.

There is no relation between the duration of symptoms or the size of the local lesion and the extent of metastasis, for some of the smallest lesions give rise to extensive metastasis, while, on the other hand, some of the most extensive local lesions give rise to very little and some to no metastasis.

The depth of the œsophageal wall involvement does not have any relation to distant metastasis, but does to local extension. The most important factor with the duration of life and the extent of metastasis is the degree of malignancy of the individual growth, which

TABLE V.—CANCERS OF THE LOWER THIRD

Sex Age	Symptoms	Type of cancer	Extent of local lesion	Metastasis	
				Above diaphragm	Below diaphragm
M. 49 5974	Loss of weight 9 mo. Pain in epigastrium 7 mo. Difficult swallowing 6 mo.	Prickle cell grade 2	Ulcerating lesion lower end of œsophagus extending into the stomach	Peri-œsophageal glands	Ulcerating tumor 7 cm. diameter in cardiac end of stomach and perforating into liver. Numerous scattered nodules in liver.
M. 56 6408	Regurgitation of solid foods 3 mo. Later liquids	Prickle cell grade 2	Obstructing and ulcerating growth lower end of œsophagus extending to gastric margin	None	None.
M. 49 6942	Weak spells and pain in epigastrium 8 mo.	Squamous cell grade 4	Flat ulcerative lesion in lower 5 cm. Extending for some distance upward in the submucosa. Dilatation above lesion	Post mediastinal nodes, trachea, scattered nodules in lung	Ulceration 2 cm. in stomach. Liver and adrenals studded. Cœliac and mesenteric nodes. Neck of humerus.
M. 65 7088	Increasing difficult swallowing 15 mo. Regurgitation	Prickle cell grade 2	Obstructing ulcerating lesion in lower 8 cm. extending into the stomach 2 cm.	None	None.
M. 69 7147	Belching 3½ mo. Difficult swallowing 3 mo. Regurgitation	Prickle cell grade 2–3	Ulceration and partial obstruction for 7 cm.	None	None.
M. 41 7384	Increasing difficult swallowing 24 mo. Several hæmorrhages from the mouth	Prickle cell grade 3	Partial obstructing flat ulceration 3 cm. by 1½ cm. wide	Mass 5 cm. in diameter invading wall of trachea. Posterior mediastinal glands	Benign ulcers in stomach gave rise to the hæmorrhage.
M. 62 7929	Difficult swallowing. Pain in epigastrium 4½ mo.	Prickle cell grade 1 to 2	Partial obstructing lesion 8 cm. Extends into the stomach where a large ulceration is present	None	Gastric and peripancreatic lymph glands.
M. 55 8496	Loss of weight and strength. Pain in back 7 mo.	Squamous cell grade 4	Partial obstructing ulcerative lesion 4.7 cm.	Œsophageal nodes	Extensive in liver. Cœliac and retroperitoneal nodes.
M. 62 8662	Marked weakness 3 mo.	Prickle cell grade 4	Flat ulcerative lesion 7 cm. in length	Empyema. No perforation of œsophagus	Mesenteric, peripancreatic and duodenal nodes. Extensive to liver.
M. 68 8892	Difficult swallowing 4 mo. Vomiting while eating	Prickle cell grade 3	Obstructing mass for lower 10 cm.	Occasional nodule in each lung.	Nodes along lesser curvature of stomach. Occasional nodule in liver.
M. 58 9932	Regurgitation 5½ mo. Pain on swallowing 2½ mo. Hæmorrhage on 3 occasions	Prickle cell grade 3–4	Partial obstructing ulceration for 4 cm.	Peribronchial glands	Glands at fundus of stomach.
M. 70 17,454	Weakness for 24 mo. Difficult swallowing 12 mo.	Prickle cell grade 2	Partial obstructing ulceration 8 cm.	Mass infiltrating trachea. Peribronchial glands	Gastric lymphatic glands along lesser curvature.
M. 65 17,579	Difficult swallowing 8 mo. Vomited blood 2½ mo.	Squamous cell grade 2–3	Partial obstructing growth 8½ cm. extending within 2 cm. of stomach	None	Lymph nodes along lesser curvature of stomach.
M. 59 5417	Pain in epigastrium. A bit of food caused him to fee filled	Squamous cell grade 3	Ulcerating and partial obstructing lesion 7 cm.	Mediastinal nodes, nodules lower lobe left lung	Liver studded. Both adrenals most replaced.

can be determined to a fairly accurate extent with the microscope. The position in which the cancer occurs in the œsophagus does not have any relation to the extent of metastasis, but does have some relation to the direction of metastasis.

Cancers of the upper third metastasize to the glands in the superior mediastinum or deep cervical glands. Those of the middle third most commonly involve the lymph glands around the bifurcation of the trachea. They metastasize below the diaphragm less

commonly and less extensively than do those involving the lower third. Cancers of the lower third most commonly metastasize below the diaphragm and this is through the cœliac chain.

The surgeon, roentgenologist, œsophagoscopist, and pathologist working together should be able to tell from the degree of malignancy of the biopsy, gross description, and individual character of a case, whether metastasis has likely occurred and if it would be worth while to subject the patient to an operation of high mortality such as resection of the œsophagus. It seems unlikely that radium will have any place in the treatment of these cancers, for the wall is involved deeply, and in most instances if the cancer cells alone could be picked out, perforation would occur and the patient would die of empyema, abscesses, or some chest complication.

INJURIES OF THE LARGE ARTERIES

Encountered in Civil Practice[1]

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INJURIES of the larger trunks of the blood vascular tree constitute but a small percentage of the accidents encountered in civil practice. While numerous statistics based on experiences gained in the recent and past wars are present concerning wounds of the blood vessels, injuries of the blood vascular tree in civil practice are usually not the result of gunshot wounds. But what chiefly distinguishes civil vascular injuries from those observed during war is their difference in etiology and in the mechanism of their production. Not included in this study are the injuries of large vascular trunks inadvertently inflicted during the course of an operation, for such wounds are under the direct control of the surgeon.

The present study is based upon 9 cases due to a variety of causes: explosion of overcharged seltzer bottles, fracture, dislocation, stab wounds, contusion without associated bone injury.

Case 1. Penetrating wound of right common carotid artery, right pleural cavity, and apex of right lung.

Patient was a female, age 22 years. The injury followed the spontaneous explosion of an overcharged, completely filled seltzer bottle. The bursting of the glass container occurred in the attempt to express some of the carbonized fluid from the bottle into a drinking glass. A shower of flying glass, forced under high pressure, immediately flew in every direction, and a number of fragments penetrated the right side of patient's neck and supraclavicular fossa. A small wound was present about 1 inch below the thyroid cartilage, medial to the anterior border of the sternomastoid muscle. Three small wounds were also present in the supraclavicular fossa.

The patient was pulseless when she was brought to the operating room. An incision was made along the anterior border of the sternomastoid muscle. The common carotid artery was wounded for more than one-third of its circumference, which arterial wound was sutured; the circulation in the vessel being controlled during the suturing by tapes above and below the vascular wound. Pulsation was present in the vessel, at the end of the operation. The pulse rate continued high, 120 to 140, and the patient became enfeebled and apathetic. Death occurred on the fourth day. At autopsy the lumen of the injured vessel was filled with a large dense red thrombus, beginning at the line of suture and extending cephalically for more than 2 centimeters.

Case 2. Penetrating wound of the left external carotid artery.

Patient was a male, age 11 years. The accident occurred in a manner similar to that in Case 1, the injury being the direct result of the spontaneous explosion of an overcharged seltzer bottle. An oblique gaping wound of about 5 centimeters was present extending medially and caudally from the angle of the mandible. The injured area was occupied by a large clot acting as a tamponade. The clotted blood was evacuated and the external carotid artery exposed. The external carotid artery between the origin of the facial and lingual arteries was severed for about one-half of its circumference.

[1] From the Daniel Baugh Institute of Anatomy of the Jefferson Medical College, and the Surgical Service of the Mt. Sinai Hospital.
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Ligation of the external carotid artery was carried out above the origin of the lingual artery. Convalescence was smooth and uneventful.

CASE 3. Stab wound of the right common carotid artery and the internal jugular vein.

Patient was a colored female, age 24 years. Following a marital altercation, patient received a knife thrust in the right side of her neck, inflicted by her gentleman friend. Examination showed that the knife blade was embedded to its very hilt in the right side of the neck. The site of the stab thrust was about 2½ inches cephalic to the middle of the clavicle. Fortunately, no attempt was made to removethe embedded weapon before the patient was sent to the hospital. At operation, an incision was made in the neck along the anterior border of the sternomastoid muscle, above and below the embedded blade. On withdrawing the embedded blade from the neck, a most alarming gush of blood ensued. The common carotid and internal jugular vein were rapidly ligated *en masse*. The necessity was for rapid and immediate control of the hæmorrhage. Whether the vagus nerve was included in the ligature cannot be stated. The patient suffered no immediate or later ill effects from the ligation, for she made a complete recovery.

CASE 4. Rupture of the left axillary artery, following the reduction of a dislocated shoulder (reported through the courtesy of Dr. P. H. McCarthy).

Patient was a male, age 67 years. Following the reduction of a subacromial dislocation of the shoulder, a definite swelling appeared in the left axilla, which gradually increased in size. The patient became pale and short of breath. The radial pulse on the affected side was not palpable. A wound of the axillary artery was suspected and operation was carried out 12 hours after the time of the reduction. An incision was made in the axilla, and the subscapular artery was found torn away from its point of origin from the axillary. Ligation of the axillary artery was performed above the origin of the subscapular. The patient died in 36 hours. Autopsy showed a complete severance of the subscapular artery as it arises from the axillary artery.

CASE 5. Wound of the brachial artery, associated with a compound comminuted fracture of the humerus.

Patient was a male, age 30 months. Injury was sustained by patient being hit with an automobile truck. On admission to hospital, patient was in profound shock, and the entire left extremity was almost avulsed. Shock treatment was instituted. Débridement of the wound was performed, and fracture fragments were placed in fair alinement. The brachial artery was ruptured about 5 centimeters above the bend of the elbow. The latter vessel was ligated. Convalescence was stormy. Some infection occurred in the wound, but the circulation in the extremity at no time appeared impaired. On discharge from the hospital, 10 weeks after the accident, the functional result was about 70 per cent. The humerus was well united and the circulation in the injured extremity presented no impairment.

CASE 6. Stab wound of the external iliac artery.

Fig. 1. The popliteal fossa, illustrating the proximal and distal fixation of the popliteal vessels. An anomalous tendon is here seen which has its origin from the short head of a biceps muscle and inserts in a fan shape fashion on the posterior medial aspect of the capsule of the knee joint. The latter muscle acts as an additional fixation agent.

Patient was a female, age 20 years. She was first seen about 30 minutes after the occurrence of the accident. She was pulseless, practically exsanguinated and unconscious.

There was a small innocent stab wound present about 1 centimeter medial to the left anterosuperior spine. This wound was the result of a stab thrust effected by the blade of a long stilleto. It was impossible to account for the sudden and complete collapse of the patient except upon the basis of an injury to one of the larger arterial or venous trunks. Shock therapy was immediately instituted. At the same time, under local anæsthesia, a rapid extraperitoneal exposure of the iliac vessels was carried out. The entire retroperitoneal space was occupied by a massive hæmorrhagic extravasation. On removal of the extravasated hæmorrhage the external iliac artery, 1 centimeter below its origin from the common iliac, was found severed for about ½ of

its circumference. No other vessel trauma was present. The wound in the artery was sutured, and the circulation above the site of injury was controlled by tapes. When the suturing was finished, pulsation of the vessel below the site of suture was easily visible. Within 48 hours, definite evidence of arterial occlusion appeared, the dorsum of foot below the malleoli showing signs of gangrene. A line of demarcation was present in 4 days. On the sixth day after the occurrence of the injury, amputation was performed about 5 centimeters above the line of demarcation. The tissues were anæmic, pale gray, and did not bleed. Fifteen days later a revision of the amputation stump was carried out. The tissues now bled freely, the muscles were red and full of life. A collateral circulation had established itself well within the 3-week period.

This patient at the present time has a useful weight-bearing stump, extending 5 inches below the tubercle of the tibia, and is able to perform all of her household duties with relatively little discomfort. Her general health is excellent.

CASE 7. Wound of right femoral artery and vein, the result of a compound comminuted fracture of the upper third of the femur.

Patient, a male, age 28 years, truck driver, was thrown off his truck, and sustained a massive wound of the upper end of the right thigh. On admission to the hospital he was in profound shock and in addition bleeding was continuous from a massive laceration on the ventral surface of the thigh. Shock treatment was instituted and the femoral artery and vein ligated. The upper end of the femur was markedly comminuted. Within 12 hours after admission, in spite of every effort, he succumbed.

Autopsy showed a complicated comminuted fracture of the upper third of the femur, the fracture fragments having torn through the femoral artery and vein.

CASE 8. Subcutaneous rupture of the left popliteal artery and vein, following the active mobilization of a stiff knee joint.

Patient a female, age 34 years, was admitted to the hospital for the purpose of breaking up adhesions about the knee joint. The affected articulation was stiff with less than 10 per cent of the normal range of movement present. Clinical and X-ray examination of this joint showed that the limitation of movement was due to periarticular adhesions and not to bony ankylosis. Under nitrous oxide anæsthesia, the knee was actively mobilized. Within 12 hours after the mobilization, the leg became cold, slightly cyanotic, and œdematous.

No pulsation was palpable in either the posterior tibial or peroneal arteries. Pain was absent over the popliteal region. Conservative treatment in the form of heat, elevation, and immobilization produced no effect, and the clinical evidence of gangrene continued to advance. An amputation through the lower third of the femur was carried out 5 days after the initial mobilization of the stiff knee joint. Dissection of the amputated extremity showed a rupture of the popliteal artery and vein midway between the adductor hiatus and the bifurcation of the popliteal artery into its anterior and posterior arteries.

CASE 9. Subcutaneous rupture of the popliteal artery and vein, the result of a football tackle.

Patient was a male, age 18. While playing football, he was tackled vigorously and roughly about the right knee and thrown to the ground. Sudden and increasing pain was immediately present in the right popliteal region. He was unable to flex or extend the knee. The popliteal fossa showed a moderate swelling which appeared to be increasing. In a number of hours, induration and moderate swelling of the calf were noted. Pulsation of the posterior tibial and peroneal arteries could not be palpated. Because of the severe increasing pain and swelling over the right popliteal area, and the induration of the leg, operation was advised, on the basis of a possible vascular injury. Operation was carried out 10 hours after injury. The right popliteal fossa was exposed through a long posterior incision. A hæmatoma of considerable size was present and evacuated. The popliteal artery was almost completely severed and occupied by small thrombus. The popliteal vein also showed a lateral tear. The artery was ligated between 2 ligatures, instead of a ligation in continuity. The popliteal vein was also ligated. The induration of the calf of the leg was probably the result of so-called anæmic induration, for there was no hæmorrhagic extravasation present in the calf of the leg.

The wound was closed without drainage. On the third postoperative day, about 2 ounces of serum were evacuated from the incision; otherwise convalescence was smooth and healing was by first intention. He was kept in bed for 21 days. The circulation of the leg is good, presents no swelling, but he has a moderate foot-drop, which, however, has not incapacitated him in any way.

CAROTID ARTERY

Wounds of the common carotid artery are preferably treated by suture. The nearer the injured vessel is to the heart, the less likelihood there is for a suture repair of the vascular wound to be followed by thrombus formation, beginning at the suture line. Frequently, however, the associated trauma permits only the application of a ligature. In the greater proportion of the reported cases of carotid artery wounds, ligation of the injured vessel was the usual procedure. Haberer (4, 5, 6) reports 8 cases in which the wound in the common carotid artery was sutured, 2 circular and 5 lateral; in one case ligation was later made, because of secondary hæmorrhage. Of the 8 cases, 7 recovered and 1 died.

In most of the reported cases, the carotid ligation was carried out for a pulsating exophthalmus, an aneurism of the carotid artery, or as a preliminary measure in operation for malignancy of the head and neck, so that much of the available information concerning the effects and dangers of carotid ligations is based on this data. The possible development of encephalomalacia with a resulting hemiplegia is always an impending danger in the ligation of the carotid artery. Sattler, in 217 ligations for pulsating exophthalmus, notes 17 fatalities upon the completion of the ligation.

In rabbits, ligation of one common carotid artery produces no noticeable effect on the animal. In a number of instances, both common carotid arteries were ligated and the result was always fatal. In man, the incidence of encephalomalacia depends upon a number of factors; first, the general state and age of the patient; second, the presence or absence of changes in the vessel walls—it was a teaching of Kocher that to tie the common carotid artery in a person past middle life was always dangerous, and in the arteriosclerotic, equivalent to a death warrant—; third, the manner of application of the ligature; fourth, the variations in the vessels forming the circle of Willis. Concerning the last, the observation of a large number of brains in the neuroanatomy laboratories of the Jefferson Medical College discloses the fact that variations in the circle of Willis are a rather common finding. Particularly significant is the presence of an exceedingly small posterior communicating artery, or complete absence of the latter vessel. Such anatomical variants undoubtedly affect the outcome of some cases.

Many of the carotid ligations cause no disturbance. Occasionally the evidence of cerebral disturbances does not appear for some hours or days after the application of the ligature.

The opinion has been expressed by a number of able observers, notably Perthes (21, 22), that the cerebral disturbances following carotid ligations are due to thrombus formation and resulting emboli. The relation of thrombus formation to a sudden and forcibly applied ligature has been noted particularly by Sigerist. In an analysis of 80 fatalities following ligation of the common carotid artery, he noted an ascending thrombus extending toward the head from the site of ligation 4 times. The thrombus foundation was the direct result of a sudden and forcibly applied ligature.

John Hunter was first to call attention to the importance of avoiding injury to vessel walls in the application of a ligature.

The contusion of a large vessel causes definite slowing of the circulation, even though the vessel is uninjured. Probably the vascular contraction noted in the operation of arterial sympathectomy can be interpreted in the same way. The vessel narrows for a time. The narrowing causes an increased resistance to the circulation because of the narrowing of the lumen of the artery, while the arterial pressure centrally remains unchanged. Injury to the vessel wall, particularly the intima, and slowing of the circulation are among the chief causes of thrombus formation. If the blood stream flows with its accustomed force, it may tear a small thrombus from the site of vessel injury, and the beginning thrombus would then form an embolus. Or the thrombus may grow into one of the adjacent collaterals and interfere with the developing collateral circulation, or may form another embolus. In brief, traumatism of the vessel and a change in velocity of the blood stream may be directly responsible for the formation of a thrombus and possible emboli.

The application of a ligature to large vascular trunks must be slow and gentle, either fascia or a thick coarse thread being used as tape. In this way one tends to eliminate injury to the intima, one of the chief causes of intravascular clotting. In the young, with soft elastic walls, it is possible to occlude the lumen of the vessel, without injury to the intima, but in the sclerotic vessel, with its friable intima, it is almost impossible to ligate an artery without intimal trauma. This latter fact represents the great danger of carotid ligation in the old.

Secondary hæmorrhage can, as a rule, be prevented as noted by Blair (1) in heeding the advice of Billroth, neither to suture any wound in the floor of the mouth nor to suture

without free drainage any wound that contains a ligated carotid or a ligated primary branch of the external carotid. In the ligation of large arteries, it is best, however, scrupulously to avoid drainage.

The prognosis in carotid ligation appears to be more favorable when it is combined with the simultaneous occlusion of the internal jugular vein. In spite of some dissenting opinions concerning the latter procedure, the observations of Oppel, Hager-Torn, Makins (18) and others, show that the hazard of arterial ligation is definitely lessened when combined with the simultaneous occlusion of the accompanying vein. Yet Rieder (23), who has had an extensive experience with arterial injuries, in 5 cases carried out the simultaneous ligation of the common carotid artery and internal jugular vein, and in each instance definite postoperative cerebral softening followed. The ligation of the accompanying vein, even though uninjured, simultaneously with the wounded artery will be discussed under the general heading of treatment.

ANATOMICAL FIXATION OF BLOOD VESSELS

The importance of the anatomical fixation of blood vessels as one of the contributing factors in the causation of vascular injuries following a severe contusing force is deserving of mention. Such anatomical fixations are present at the sites where branches of considerable size take origin. Instances of the latter are the sites of origin of the subscapular and posterior humeral circumflex from the axillary artery, and the bifurcation of the popliteal artery into the anterior and posterior tibial.

Clinically, this anatomical fact is well illustrated in the type of vascular injury observed incident to the occurrence or to the reduction of a dislocated shoulder. The greater proportion of the available reported cases of axillary artery wounds associated with a dislocated shoulder shows that the type of vascular injury encountered is that either the subscapular or posterior humeral circumflex artery is torn away from its point of origin.

Koerte (10, 11) in 1882 reported 2 such accidents in his own experience. In 1902 he added another personal case and collected 44 cases from the literature. Of the 44 collected cases, one-half of them were in recent dislocations, and in more than one-third of the latter group, the vascular rupture took place during the act of reduction. In only 3 of the entire group was it definitely established that the arterial wound occurred with the dislocation. Furthermore, in 20 instances of the 44, the vascular wounds occurred during the reduction of old dislocations. Koerte considered 2 months or more as an arbitrary time division period between recent and old dislocation. Stimson (27) in 1885 reported 44 axillary artery wounds following dislocation of the shoulder. Of the 44 cases, 12 recovered and 32 died.

The noteworthy fact concerning the association of axillary artery wounds with dislocation of the shoulder is that this vascular injury occurs in the majority of instances from the movements and maneuvers usually practiced when a dislocated shoulder is reduced. Excessive violence and excessive traction must be avoided. The presence of arteriosclerosis necessitates extreme care in reduction. It is when the reduction is difficult that a wound of the axillary artery is likely to take place. In the reduction of an old dislocation, particular care must be exercised, and an open operation is the advisable procedure, if the reduction cannot easily be effected. Even the Kocher method of reduction is not without danger in this respect; for marked pressure on the axillary vessels is produced in carrying out the Kocher method of reducing a dislocated shoulder.

The prevention of the possible occurrence of this injury merits a brief consideration. Formerly there was a general belief in the importance of the ligaments for the fixation of joints, but at present there is a tendency to believe that the tonic activity of muscles is the most important factor. In his series of marvelous experiments Sherrington shows that, in ordinary movements, muscles obey the law of reciprocal innervation. Antagonistic muscles exert synergistic action and fix the joint.

Iselin (9) has developed a method of reducing a dislocated shoulder which the writer has used in a modified form with uniformly successful and satisfactory results. It is in

reality a maneuver of active self reduction on the part of the patient and depends essentially upon the premise postulated by Sherrington. No anæsthetic is required, thus the necessity of all manipulative force being reduced. This method of reduction is carried out as follows:

The arm is placed so that the elbow rests against the anterosuperior spine of the ilium. The arm is first raised slightly in the sagittal plane. The patient is instructed to perform external rotation forcibly, the latter movements being aided by the surgeon, who at the same time adducts the arm. The simultaneous action of the opposing movements of external rotation and abduction and adduction with internal rotation, permits the head of the humerus to slip quietly into the glenoid cavity. There is no audible click on reduction, when this technique of reduction is practiced. It is carried out more easily and rapidly than the Kocher and other methods and tends to eliminate the hazard of arterial injury.

In the case of the popliteal artery, additional anatomical relations render this vessel more prone to injury from a contusing force. The vessels of the lower extremity, particularly in the popliteal space, are in more intimate relation to the bone. Figure 1 illustrates the proximal fixation of the popliteal artery and vein, at the adductor hiatus, where it is firmly fixed by the adductor magnus tendinous arch. Distally these vessels are again fixed by the tendinous arch of the soleus muscle, and by the anterior tibial artery as it passes through the interosseus membrane. The anatomical nearness of the popliteal artery to the posterior surface of the femur and its proximal and distal fixations are the latent anatomical factors which explain its subcutaneous vascular rupture, the result of a severe contusing injury, without an associated bony injury.

Cases 8 and 9 are illustrative instances wherein the popliteal vessels were ruptured yet no bony injury was sustained. The active causes of these 2 popliteal vessel wounds were as follows: Case 8 resulted from active mobilization under anæsthesia of a stiff knee joint; Case 9 resulted from being tackled in a football game. In the majority of instances the suddenness of the applied violence or movement induces a marked tension and distention of the vessel wall. The elastic tissue of the vessel wall offers but little protection against injury from a sudden violence in the case of the popliteal artery. The maximum distention of the vessel wall may not be reached, but the suddenness of the violence ruptures the vessel because of its natural anatomical fixation.

The mechanism of this vascular wound has been aptly compared to a taut string which is held firmly fixed at either end; should a sudden pressure or pull be applied, its center would tend to give away.

Pictured in Figure 1 is a large anomalous tendon, which courses obliquely across the popliteal space. Certainly this tendon, when present, would act further to fix the popliteal vessels. While the finding of such a tendon is a rare event, it must be recognized that the subcutaneous rupture of the popliteal vessels is also a rare occurrence.

Wounds of the popliteal artery which are the result of dislocation of the tibia have been reported in a number of instances. Schulz (25) reports the occurrence of a popliteal rupture in a young adult following the reduction of a dislocation of the tibia. Bruenner (3) reports 4 instances of subcutaneous ruptures of the popliteal artery, 3 of which resulted from dislocations of the tibia.

Here again the anatomical fixation of the vessels and the well-known fact that when the leg is extended, the popliteal vessels do not rest on the bony surface, account for a possible rupture of the popliteal vessels, if the leg is suddenly overextended as in an anterior dislocation of the tibia.

COLLATERAL CIRCULATION

Certainly the establishment of an adequate collateral circulation, following the ligation of a large vascular trunk, must take some time. In the experimental ligation of large arteries in animals, the development of a definite collateral circulation, takes from 15 to 21 days, depending upon the vessel ligated, and the site of the ligation. It is well to remember, however, that large arterial trunks can be ligated in animals with considerable less fear of gangrene than in man.

In Case 2 in which the external iliac artery was sutured, gangrene of the foot developed, probably as the result of thrombus formation at the suture line. An amputation was performed within 4 centimeters of the line of demarcation, at which time the muscles were pale, dull gray in appearance, and the entire procedure was free from bleeding. Three weeks later a revision of the stump was carried out, and the appearance of the tissues found markedly changed. The muscles were red, glowing with a healthy normal color, and bleeding from the cut tissues was most active. The time for the establishment of the collateral circulation in this instance was within the 3-week period.

X-ray studies of amputated extremities supplemented by later dissections of the specimens appear to indicate that the arteries accompanying the various nerves are among the most important of the vessels concerned in the formation of an adequate collateral circulation. Experimental ligations of the femoral artery show that the establishment of an efficient collateral circulation following the ligation, depends mainly upon the sciatic artery. The vasa nervorum accompanying the various nerves are sometimes vessels of some size, and in addition they anastomoses freely with other arterial twigs to form a continuous vascular network. When a large vascular trunk is occluded or ligated, the vasa nervorum undergo an increase in their lumen establishing an excellent collateral circulation. Variations in the caliber and in the anastomatic arterial network of the vasa nervorum are vital factors in the formation of an efficient collateral circulation.

The pure morphological factor and its relation to the development of a collateral circulation is not sufficiently recognized and has not been given the attention it deserves. While in the main the variations of the larger arterial trunks tend to conform to a number of well defined anatomical types, the variations of the smaller arterial twigs are so highly individualistic as to defy analysis. And it is not unlikely that such arterial individualism, if means of recording and measuring them were possible, would be as distinctive as one's finger prints.

Attention has been particularly focused on the question of pressure, exchange of substances in the vessel and vessel walls, the tonicity of the capillary bed and tissue needs, but the pure morphological element is usually overlooked. The marked variations in the blood vascular tree, surely must have no little influence in the establishment of an efficient collateral circulation. In a number of studies on the variations of the blood vascular tree (15, 16, 17), it is noteworthy that a finding of definite hypogenesis of the blood vessels occurs in approximately 8 per cent of all cadavers. This hypogenesis consists of definitely smaller calibered blood vessels and a decrease in the number of branches. The microscopic image confirms the latter finding, for the examination of a considerable number of arterial walls shows a wide variation in the general mural structure. The elastic content, the muscle content, etc., exhibit wide variations. In some instances the vessel, because of its faulty mural structure, appears almost fragile; in other cases strong and robust. Such findings are recorded independent of age and disease, and represent distinct morphological types.

Conversely considered, the presence of additional branches, the presence of accessory arteries are not uncommon findings in the experience of any observant anatomist.

Surely such factors as outlined above represent important elements concerned in the formation of an excellent collateral circulation, entirely apart from the pure physico-dynamic factors. The writer in no way underestimates the physico-dynamic factors concerned in the formation of a collateral circulation but desires to call attention to this morphological aspect.

TREATMENT

Wounds of the blood vascular tree in which the evidence of hæmorrhage is not severe and no continuous increase in size of the hæmatoma appears, may for a time be treated conservatively. Numerous observations are present to show that the spontaneous cessation of hæmorrhage is possible in cases of injuries to large vessels. There are a number of remarkable instances on record in which the

vascular trauma present would have seemed to render a fatal issue inevitable, yet recovery ensued without an operation. Injuries which involve both the artery and its accompanying vein appear to show a greater tendency to spontaneous cessation of hæmorrhage. The spontaneous healing of arterial trunks, partially or completely divided, has come to light largely by discovery of the vascular lesion in the course of operations upon nerves. Makins remarks that the great majority of these instances are due to contusion. Vascular lesions which are the result of a severe contusion may not effect a complete break in the vessel wall. Herzog (7) in 30 such injuries found the intima alone injured 9 times, the intima and the media 21 times. Sebestyen (26) questions whether the spontaneous cessation of hæmorrhage occasioned by an injured vessel is not dependent for its cessation upon the equalization and balance of pressure. Thus small vessels bleed less, for the pressure is easily balanced. He believes that the bleeding stops spontaneously when the pressure of the extravasated blood in the tissues is as great as the pressure of the blood in the injured vessel. Obviously the contraction of the vessel wall is also a factor. Thus, injury of the popliteal, femoral, or of some other large vascular trunk may temporarily stop bleeding, in the absence of an obstructing thrombus.

Should evidence of progressive hæmorrhage exist and the hæmatoma present increase in size, operation is indicated without delay. The deliberate delaying of operation in the presence of a large hæmatoma the result of an injury to one of the large vessels has two hazards: first, the pressure of the hæmatoma on the surrounding vessels, which interferes with their participation in the establishment of a collateral circulation—the true causes of gangrene when it occurs after ligature or suture are those which interfere with the establishment of the collateral circulation—; second, the danger of infection of the hæmatoma, for with infection, besides sepsis, there is the additional hazard of a secondary hæmorrhage. Infection is probably the most frequent cause of secondary hæmorrhage.

The danger of hæmorrhage following the removal of a retained foreign body deserves mention. Such a retained foreign body may act as a vascular plug, or may control bleeding from an injured vessel by pressure, and its removal may set up a most alarming hæmorrhage. The surgeon must have this possibility in mind in the removal of a retained foreign body lying in the neighborhood of large vascular trunks and be prepared before and during the operation for such an emergency. Case 3 is an example in this group. The patient, a colored female, was admitted to the hospital with the blade of a knife embedded in the left side of the neck, so that only the handle protruded. Fortunately no attempt was made to withdraw the embedded weapon before the patient was transferred to the operating room. When the knife was withdrawn a most alarming hæmorrhage ensued. Both the carotid and jugular vein had been severed. The wounded artery and vein were ligated. Recovery was uneventful.

The question as to whether the injured vessel should be treated by the obliteration ligature or the conservative suture has been admirably summed up by Matas (19), La Roque (14), and others, and the consensus of opinion decidedly favors the ligature. The decision in favor of the aseptic ligature is based on the end-results; that ligation is usually an easy procedure and the suture often a difficult one is entirely outside the question.

In two of the cases included in the series of arterial injuries (external iliac, common carotid), repair of the injured artery was carried out by careful suture. In both instances, definite thrombus formation resulted, extending cephalad from the line of suture. In regard to thrombotic occlusion, the experimental evidence shows that even in the best conditions, in laboratory animals, the suture, especially the circular suture, is liable to a very considerable percentage of failures through thrombotic occlusion or cicatricial stenosis. Before the war, Matas collected from the literature reports of 49 circular sutures which had been performed in civilian hospitals and in peace conditions. A careful analysis of the available postoperative evidence showed that 13.1 per cent had been followed by gangrene. Of the 37 patients who recovered, in no less than 33 (87.6 per cent)

by circular suture with and without interposed grafts, the anastomoses had proved functionally valueless or superfluous, if we are to judge by behavior of peripheral pulses.

The margin of the safety must always lie, whether with the suture or ligature, in the integrity of the collateral circulation. A properly applied ligature suffices to meet almost every pressing indication. From my own small clinical experience, ligation (external carotid, popliteal, common carotid, brachial) has resulted in recovery.

The value and the necessity of ligating the accompanying vein, even though uninjured, in cases of arterial ligation, is variously interpreted. The study of any problem concerning the blood vascular tree must represent a consideration of the circulatory system in total perspective, as a closed hæmodynamic apparatus subject to potential variations and oscillations. Many believe that the danger of arterial ligation is greatly decreased by the simultaneous ligation of the accompanying vein. The clinical experience of Makins, Oppel, Hagern-Torn, Neuhof, and St. John (20) and Holman and the experimental analysis of this problem by Brooks (2) and Holman (8) show a decided decrease in the incidence of gangrene when the artery and vein are simultaneously occluded. In two of the included case reports, both the artery and vein were ligated (popliteal and common carotid), and the recovery was without note in each instance. Holman advises the ligation of common femoral vein above the deep femoral or even long saphenous in ligation of the popliteal artery, in order, under certain circumstances, to increase the capillary resistance in the thigh, and, by directing the force of the collateral circulation into the anastomotic channels, to lessen the possibility of gangrene. Ligation of the vein nearer the heart is recommended after ligation of popliteal artery and vein, if gangrene is suspected, but it must be performed before true gangrene supervenes.

Makins believes that the combined procedure maintains within the limb the smaller amount of blood supplied by the collateral circulation. Whatever may be the factors that determine the formation of an efficient collateral circulation, surely pressure must be an important one; for change of pressure interferes in some degree with the necessary stimulus for vascular dilatation and exchange of substances through the capillary walls. Blood is serviceable to the tissues in the capillary region only and there is a definite relation between blood pressure and permeability. Furthermore in the examination of capillary fields there is a distinct difference between arterioles and capillaries. Between the capillaries and venules the difference is much less pronounced. The muscular walls of many venules is so thin and incomplete that the exchange of substances through their walls must be considerable, and in some cases the vessels which are classed as veins are, from a physiological point of view, to be regarded as capillaries. Simultaneous ligation of the artery and vein would seem to maintain a more equable pressure equilibrium in the important functioning capillary bed. While the caliber of the capillaries is mainly determined by their own tonus, it is of course also affected to a certain degree by the blood pressure (Krogh, 13). In some experimental studies concerning the value of the combined procedure, Krampf (12) of Sauerbruch's clinic advises against the ligation of the vein. He used the kidney as the basis of his work, but his results are by no means convincing. The fact that the arteries and capillaries in normal subjects vary greatly and the fact that the power to resist an internal pressure is developed to a different degree in the capillaries of different tissues are entirely overlooked. Without an attempt to saddle this thesis too heavily with this phase of vascular surgery, the balance of opinion both clinical and experimental strongly favors the simultaneous ligation of the artery and vein. The only contra-indication to the ligation of the vein as noted by Brooks is evidence of obstruction in the collateral veins.

The operation in cases of arterial wounds necessitates a generous exposure of the injured vessel. Every effort must be made to conduct the operation aseptically, in order to eliminate the hazards of thrombosis and infection. Drainage in vascular surgery must be scrupulously avoided. Packing and drainage as Holman notes invite disaster. The ligature

must be applied gently, to occlude the lumen of the vessel without intimal injury. Studies by Schaeffer (24) at the Baugh Institute of Anatomy on the obliteration of the lumen of blood vessels indicate that injury to the endothelium, incident to ligation, may result in intravascular clotting and thrombus. In one series of ligations, thrombosis was of common occurrence, while in a second series it was rare. Halsted, Holman, and others advise the use of coarse ligatures such as tape, rather than fine ligatures which may cut through the arterial wall. This has been our practice. In the one popliteal ligation, the artery and vein were divided between ligatures instead of ligating in continuity. Holman has again directed attention to the value, when feasible, of dividing the vessel between two ligatures. He considers this procedure preferable to ligation in continuity.

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THE EFFECTS OF ETHER, CHLOROFORM, AND ETHYL CHLORIDE ANÆSTHETICS ON THE MINUTE CARDIAC OUTPUT AND BLOOD PRESSURE

An Experimental Study

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THE death rate which is ascribed to the administration of various anæsthetics is remarkably low at the present time. This fact is due in large part to the increased information concerning the physiological action of these drugs and to the careful consideration as to the choice of anæsthetic in individual cases. However, studies upon the actual output of the heart of the intact experimental animal have been neglected. Since it is thought that this is one of the best, if not the best index of the condition of the circulation, the present study was attempted. Many of the observations, such as determinations of the blood pressure and hydrogen-ion concentration can be performed on the anæsthetized patient, but studies upon the cardiac output cannot be carried out because of the dangers of puncturing the heart and of the inaccuracy of indirect methods. Hence, it was necessary to use animals in this study.

The prevailing ideas concerning the effects of various anæsthetics on the circulation have been formed mainly from studies on the blood pressure and from observations on the isolated heart. Some of this work has revealed findings of great significance, but deductions from such studies as to the output of blood by the heart of intact animals are not justified and in some instances have been found to be erroneous. In previous experiments (1) it was found that ether caused an increase in the cardiac output provided the animals were not too deeply anæsthetized. It was also found that the amount of increase in the cardiac output from the administration of ether could be lessened by the intravenous injection of an alkali or by the previous administration of digitalis. In the present report, the changes which were found during ether anæsthesia are of interest only in comparison with the changes noted when chloroform and ethyl chloride were administered to approximately the same degree. Many previous reports on the blood pressure during the administration of various types of anæsthetics are found in the literature and the present figures are of interest only in relation to the changes in the cardiac output.

METHODS

The studies consisted of 87 determinations of the cardiac output of 24 dogs. Eleven of these animals were trained to remain quiet without a narcotic, while the remaining animals were given morphine (usually .06 grams) about an hour before the control observations were made. The blood pressure was determined in 7 of the narcotized animals.

After one or more control determinations, one of the anæsthetics was administered through an open cone. The degree of anæsthesia was probably variable, but an attempt was made to secure general relaxation and abolition of the lid reflexes. When the desired degree of anæsthesia was obtained, blood samples were drawn with the cone in place and during the continued administration of the anæsthetic. The oxygen consumption was then determined immediately after removing the cone. This method is open to criticism, but since the changes in oxygen consumption were small and since the animals were usually deeply anæsthetized, it is presumed that the error is small.

The oxygen consumption was determined by means of a Benedict spirometer with a graphic recording device. The animal was connected to the spirometer by means of a rubber mask (2), which fitted tightly over his mouth.

The usual precautions against contact with air were observed in the collection of blood

TABLE I.—THE EFFECT OF CHLOROFORM AND ETHER ANÆSTHETICS ON THE CARDIAC OUTPUT AND BLOOD PRESSURE

Date	Weight kgms.	Pulse rate per min.	Temperature F.	Arterial O_2 Vols. per cent	Venous O_2 Vols. per cent	A.V. Difference Vols. per cent	O_2 Consumption c.cm. per min.	Cardiac output per min. c.cm.	Output per kgm. per min. c.cm.	Output per beat c.cm.	Mean blood pressure mm. Hg.
12–21–26 3:00 p. m., control study	13.6	60	98.6	18.84	12.48	6.36	88.2	1387	102	23	125
3:55 p. m., after chloroform for 15 minutes	13.6	50	98.6	18.84	12.36	6.48	86.4	1333	98	27	104
4:05 p. m., after chloroform for 25 minutes	13.6	55	98.6	19.56	11.64	7.92	82.8	1045	77	19	109
5:10 p. m., control study	13.6	72	99	18.24	12.84	5.40	86.4	1600	118	22	109
5:55 p. m., after ether for 15 minutes	13.6	120	99	18.96	14.88	4.12	97.2	2359	174	19	110

Protocol: 12–21–26, one grain of morphine at 11:00 a.m. 3:00 p.m., control determinations. 3:40 p.m., chloroform anæsthesia begun. 3:55 p. m. animal breathing chloroform, lightly anæsthetized, cardiac output and blood pressure. 4:05 p.m., dog slightly more deeply asleep, lid reflexes obtainable, cardiac output and blood pressure. Anæsthesia stopped at 4:07 p.m. 5:10 p.m., control determinations. 5:40 p.m., ether anæsthesia begun. 5:55 p.m., animal anæsthetized, lid reflexes obtainable, cardiac output and blood pressure determinations.

samples. Arterial blood was obtained by puncture of the left ventricle or one of the femoral arteries, and venous blood by puncture of the right ventricle. The blood gas determinations were made on the Van Slyke-Neill (12) manometric apparatus. The circulatory minute volume was calculated from the Fick formula:

$$\frac{\text{C.cm. } O_2 \text{ consumed per minute}}{\text{Amount } O_2 \text{ taken up in lungs by 1 c.cm. of blood}} = \text{No. c.cm. of blood flowing through the lungs per minute.}$$

When the effect of more than one type of drug was studied, the same animal was used and sufficient time was allowed to elapse for complete recovery from the previous anæsthetic.

RESULTS

The results are divided for convenience into three groups according to the type of anæsthetic employed.

I. *Ether anæsthesia.* Previous experiments upon the effect of ether anæsthesia are reported in detail elsewhere. The present studies are of interest mainly in the comparison which they afford with the other two anæsthetics.

The experiments with ether anæsthesia were performed upon 8 animals, 5 of which were trained and remained quiet during the control studies without a narcotic. The same results were obtained with both the trained dogs and those which were given morphine. The cardiac output increased during the administration of the ether anæsthetic in each of the 8 experiments, the percentage increase over that during the control period varying from 4 to 44 per cent. The oxygen consumption usually remained about the same and the utilization of oxygen (arterial oxygen content minus venous oxygen content) decreased in 7 of the 8 experiments. The pulse rate was accelerated in all instances. The blood pressure was determined in 3 experiments. At the beginning of the anæsthesia there was a marked rise in blood pressure which rapidly declined, but the blood pressure then remained at a slightly higher level than that of the control period. The results of three typical experiments are given in Tables I, II, and III.

II. *Chloroform anæsthesia.* Fifteen animals were used in this study, 8 of which were trained and did not require a narcotic. It is believed that the degree of anæsthesia which was obtained with chloroform was usually not so deep as that with ether. The pulse rate usually increased, but not so much as with ether. The oxygen consumption was decreased slightly in most experiments. The utilization of oxygen was increased in all instances except two. Changes in the cardiac output paralleled alterations in the arteriovenous difference rather than changes in oxygen consumption. The decrease in minute cardiac output varied from 4 to 50 per cent, the amount of decline seeming to be directly proportional to the depth of the anæsthetic. The average decrease in the cardiac output

TABLE II.—THE EFFECT OF ETHYL CHLORIDE, ETHER, AND CHLOROFORM ANÆSTHETICS ON THE CARDIAC OUTPUT AND BLOOD PRESSURE

Date	Weight kgs.	Pulse rate per min.	Temperature F.	Arterial O_2 Vols. per cent	Venous O_2 Vols. per cent	A. V. Difference Vols. per cent	O_2 Consumption c.cm. per min.	Cardiac output per min. c.cm.	Output per kg. per min. c.cm.	Output per beat c.cm.	Mean blood pressure mm. Hg.
12–14–26. 1:35 p.m., control study	14.5	50	99	21.6	15.84	5.76	95.4	1656	114	33	100
12–14–26. 2:35 p.m., 5 minutes ethyl chloride	14.5	104	99	22.80	7.56	15.24	90.5	594	41	6	100
12–14–26. 2:42 p.m., 12 minutes ethyl chloride	14.5	108	98.5	23.40	17.88	5.52	98.7	1788	123	17	92
12–15–26. 12:05 p.m., control study	14	90	98	20.88	15.24	5.64	90.0	1596	114	18	109
12–15–26. 12:30 p.m., control study	14	95	98	20.88	15.36	5.52	90.0	1630	117	17	110
12–15–26. 12:53 p.m., ether for 13 minutes	14	170	98	18.36	15.12	3.24	93.6	2889	.206	17	115
12–15–26. 2:00 p.m., control study	14	105	99.5	20.52	13.56	6.96	115.2	1655	118	16	112
12–15–26. 3:20 p.m., chloroform for 15 minutes	14	180	99.5	20.40	13.44	6.96	100.8	1448	103	8	95

Protocol: 12–14–26, 11:00 a.m., morphine grains, one. 1:35 p.m., control cardiac output and blood pressure determinations. 2:15 p.m., second control blood pressure. 2:30 p.m., ethyl chloride begun. 2:35 p.m., determinations, lid reflexes not obtainable. 2:42 p.m., cardiac output determined, lid reflexes obtainable.
12–15–26, 11:00 a.m.; morphine grains, one. 12:05 p.m., control studies, blood pressure and cardiac output. 12:30 p.m., control studies, blood pressure and cardiac output. 12:40 p.m., ether anæsthesia begun, blood pressure being recorded at the time. 12:53 p.m., eye reflexes barely obtainable, cardiac output and blood pressure. 2:00 p.m., dog seems completely recovered from ether anæsthetic, control determinations of cardiac output and blood pressure. 3:05 p.m., chloroform anæsthesia begun. 3:20 p.m., dog lightly anæsthetized with chloroform, lid reflexes easily obtainable, cardiac output and blood pressure. Dog seemed in excellent condition at end of experiment.

was 28 per cent. Changes in the oxygen content of the arterial blood were negligible. Arterial anoxæmia was not found in any instance. The decrease in the oxygen content of the venous blood was usually quite marked. Chloroform anæsthesia was usually associated with a decrease in the carbon dioxide content of both the arterial and venous blood. The mean blood pressure was found to be lower during the anæsthetic in each case in which it was determined.

The results of three typical experiments are given in Tables I, II, and III. Figures 1, 2, and 3 contrast graphically the effects of the three anæsthetics under consideration.

III. *Ethyl chloride anæsthesia.* The experiments with ethyl chloride anæsthesia were performed on 11 animals, 4 of which did not require a narcotic. It is much more difficult to study the effects of this drug, because of the very narrow zone which separates the lethal from the toxic dosage. A great variation in results was obtained depending upon the degree of anæsthesia.

The inhalation of ethyl chloride caused only a slight increase in the pulse rate. The oxygen consumption was usually slightly decreased. Changes in the arteriovenous difference were variable, but it was usually slightly increased. Arterial anæmia was encountered in two experiments. The average change in cardiac output was −14 per cent, but the changes varied from +10 to −64 per cent. The mean blood pressure was elevated during the early part of the anæsthesia, but then returned to a level slightly below the control line. The average change in blood pressure at the time of the determination of the cardiac output was −5 per cent.

It is seen from these experiments that the effects of ethyl chloride are quite variable. The early stages of anæsthesia are thought to be associated with a slight increase in the cardiac output, while deeper narcosis causes a marked decrease. The effects on the circulation seem to be intermediate between those of ether and chloroform.

DISCUSSION

The factors which may possibly explain the increase in the cardiac output during ether anæsthesia have been previously con-

TABLE III.—THE EFFECT OF CHLOROFORM, ETHER, AND ETHYL CHLORIDE ANÆSTHETICS ON THE CARDIAC OUTPUT

Date	Weight kgs.	Pulse rate per min.	Temperature F.	Arterial O_2 Vols. per cent	Venous O_2 Vols. per cent	A. V. Difference Vols. per cent	Arterial CO_2 Vols. per cent	Venous CO_2 Vols. per cent	O_2 Consumption cc. per min.	Cardiac output per min. c.cm.	Output per kg. per min. c.cm.	Output per beat c.cm.
10–12–26. Control study, no morphine	22.0	85	102	17.28	11.28	6.0	41.19	48.89	248.4	4140	188	49
10–13–26. 3 p.m., control study, no morphine	21.6	120	102.6	16.59	11.38	5.21	45.49	49.52	252.0	4837	223	40
10–13–26. 5 p.m., after chloroform for 18 minutes	21.6	100	102	16.22	8.24	7.98	43.68	46.18	259.2	3248	150	32
10–13–26. 10 p.m., control study, no morphine	21.6	110	102	16.46	11.51	4.95	39.09	41.03	241.2	4873	226	44
10–13–26. 11 p.m., after ether for 23 minutes	21.6	200	102	17.56	13.68	3.88	33.11	35.61	230.4	5938	275	30
11–10–26. 3 p.m., control study, no morphine	21.5	80	102.5	16.92	10.92	6.0	43.16	46.03	282.6	4710	219	59
11–10–26. 4 p.m., control study, no morphine	21.5	85	102.5	15.96	10.56	5.40	42.2	47.95	252	4670	217	55
11–10–26. 4:45 p.m., after ethyl chloride for 15 minutes	21.5	150	102	16.8	10.32	6.48	24.66	29.04	285	4398	205	29

Protocol: 10–12–26, control study without morphine on healthy dog. 10–13–26, 3:00 p.m., control study without morphine. 5:00 p.m., blood samples taken after chloroform had been administered for 18 minutes, lid reflexes barely obtainable. 10:00 p.m., control study without morphine. 11:00 p.m., blood samples taken after ether had been administered for 23 minutes, lid reflexes not obtainable. 11–10–26, 3:00 p.m. and 4:00 p.m., control studies without morphine. 4:45 p.m., determinations after ethyl chloride for 15 minutes, dog not very deeply anæsthetized at time blood samples were drawn.

sidered. The present report consists of a series of observations on the cardiac output and blood pressure during ether, chloroform, and ethyl chloride anæsthetics. No attempt has been made to determine the manner by which these changes take place. However, the findings by other experimenters are of interest in this regard.

Kodama (9) studied the output of adrenalin by the suprarenals during ether and chloroform anæsthesia. The output was found to be diminished by both of these anæsthetics. Since the cardiac output is affected differently by the two drugs, it does not seem likely that the change is instituted by the adrenals.

It is known that anoxæmia may be associated with any of the anæsthetics under discussion. Harrison and Blalock (8) have found that anoxæmia of a severe degree causes an increase in the cardiac output. However, the arterial blood was normally saturated with oxygen in practically all of the present experiments and no relationship seemed to exist between the percentage saturation and the cardiac output. Leake and Hertzman (10) state that it is impossible to maintain anæsthesia under nitrous oxide and oxygen without some anoxæmia. Although the effect of nitrous oxide on the cardiac output of the intact animal cannot be studied satisfactorily by available methods, it seems probable that an increase in the output of the heart is associated with it.

Various observers have found that ether and chloroform cause an increase in the hydrogen-ion concentration of the blood. Harrison, Wilson, and Blalock (7) studied the effects of acidosis and alkalosis on the cardiac output of dogs. Injection of large amounts of acid caused an increase in the cardiac output, while the injection of alkali resulted in a decrease in the cardiac output. Previous studies (1) have shown that all of the increase in the cardiac output during ether anæsthesia is not due to the acidosis which is produced. Since the administration of chloroform causes an increase in the hydrogen-ion concentration of the blood and a decrease in the cardiac output, it seems likely that the change in the output of the heart is not due to alterations in the reaction of the blood.

As regards the effect on the peripheral circulation, Cushny (4) states that both ether and chloroform dilate the vessels when they

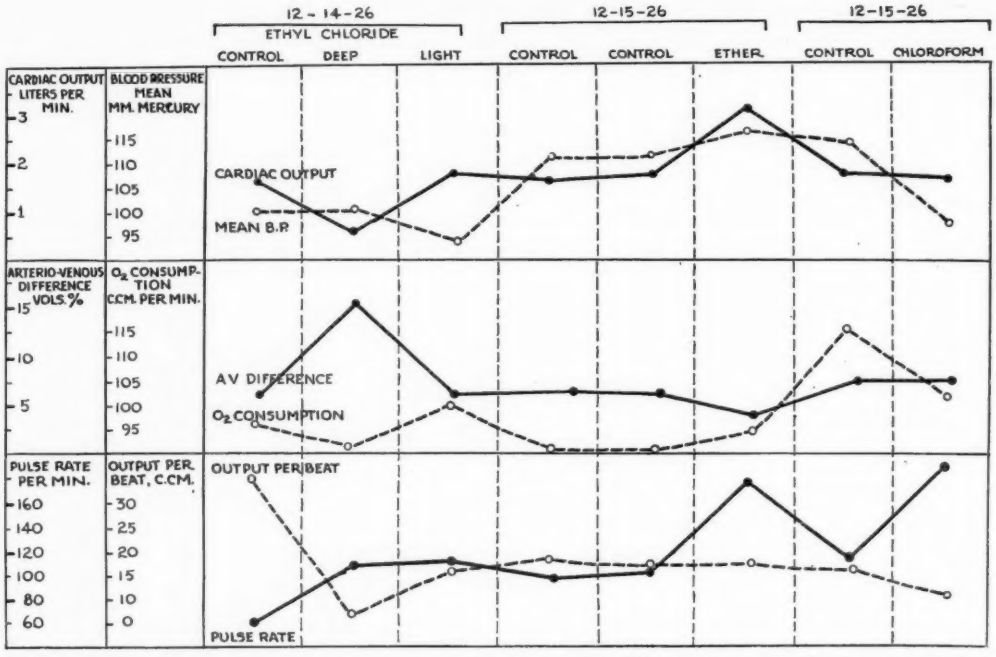

Fig. 1. Showing the changes during the anæsthesia induced by ethyl chloride, ether, and chloroform in a typical experiment. It is to be noted that the changes in the cardiac output and blood pressure were variable under ethyl chloride and that both of these functions were elevated during ether anæsthesia and depressed during chloroform anæsthesia.

are perfused through them. Embley (5) in studying the pharmacology of ethyl chloride and chloroform, states: "The net result of the action of ethyl chloride upon the vascular system, therefore, is dilatation, but the degree of paralysis is strikingly less than that produced by chloroform, even when the latter is present in less than one-tenth the quantity in the air inspired." Ranson, Winkle, and Faubion (10) injected ether into the iliac artery and noted first a vasoconstriction and later a vasodilatation and swelling of the limb. If the effect on the peripheral circulation of each of these anæsthetics is a vasodilatation, it indicates that other factors are primarily responsible for the varied alterations in the cardiac output which they cause.

The different effects of these anæsthetics on the heart itself are thought to be of more importance. This view is somewhat in contrast to some of the opinions which have been expressed. Cushny (4) states: "The frog's heart under chloroform or ether beats more slowly and more weakly, and at the same time undergoes a certain amount of dilatation, all owing to the paralyzing effects of these drugs on the cardiac muscle." Cattell (3) stated that a depression of the heart and a decrease in its output were initiated at the very beginning of ether anæsthesia. However, Gwathmey (6) states: "Ether becomes a cardiac depressant only in the later stages of anæsthesia, or when a toxic amount is employed." Embley (9) states: "The effect of ethyl chloride on the heart muscle, as is the case with chloroform and in contrast with that of ether, is paralytic, but the quantity of ethyl chloride vapor in the air required is 19 times as great as that of chloroform to produce comparable results." He attributed the sudden fall in blood pressure during ethyl chloride anæsthesia to vagus inhibition of the heart, while the later decline was thought to be due primarily to cardiac paralysis, which was later accentuated by

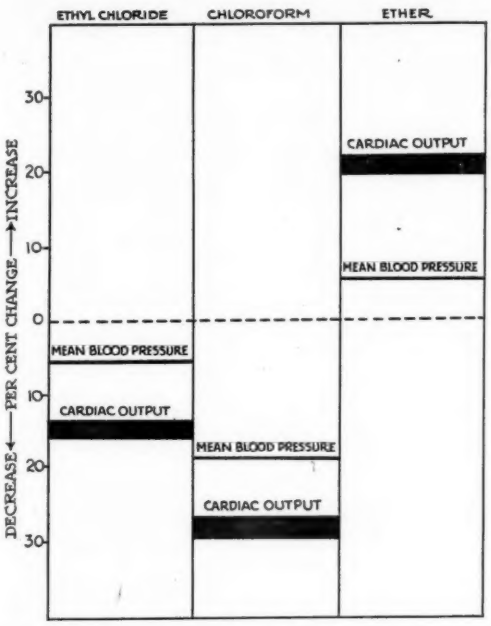

Fig. 2. This figure represents graphically the average percentage change in all experiments in the cardiac output and blood pressure. The striking difference in the effect of ether and chloroform is noteworthy.

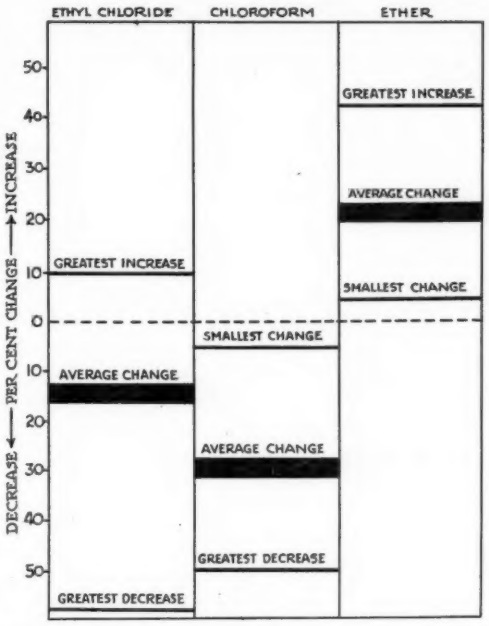

Fig. 3. It is to be noted in the present experiments that ether anæsthesia caused an increase in the cardiac output in every instance, that chloroform caused a decrease, and that the effect of ethyl chloride was variable.

vagus inhibition. These latter observations, together with the present report, suggest that the factor of primary importance in regulating the cardiac output during the inhalation of these three anæsthetics is the action on the heart itself.

It is rather striking (Fig. 2) that the directional changes in the blood pressure during the various anæsthetics are the same as those in the cardiac output, but to a lesser degree. This fact emphasizes the stability of the blood pressure and suggests that the changes in blood pressure are secondary to alterations in the cardiac output.

It is impossible to state at the present time what effect these anæsthetics have on the minute output of the heart of man. However, practically all drugs have similar actions on man and dog. Furthermore, the arteriovenous difference of blood from the femoral artery and vein has been determined in 4 patients before and during the administration of ether anæsthetics. The utilization of oxygen was decreased in each of these instances, indicating a more rapid circulatory rate.

The findings with ethyl chloride are in support of the prevailing clinical impression that the margin of safety is small with this drug and that it is not suitable for long-continued anæsthesia. Since ether and chloroform anæsthetics cause opposite directional changes in the cardiac output and blood pressure, it seems from the viewpoint of their action on the circulatory system, that these two drugs should not be used interchangeably.

Our present knowledge of the advantages and disadvantages of these anæsthetics in patients with heart disease is far from being complete. It is believed that the work here reported is a contribution toward the solution of this problem, but a final evaluation of the anæsthetics which are employed in patients with cardiac disease cannot be made until more knowledge is available concerning the

pathological physiology of the circulation, particularly the minute output of the heart, in circulatory disorders.

The possible means by which these changes are instituted are discussed.

SUMMARY

The cardiac output and the blood pressure of the dog have been studied during the administration of ether, chloroform, and ethyl chloride anæsthetics. Some of these experiments were performed on trained animals, while in others the animals were narcotized with morphine. The results were the same whether or not morphine was used.

The more significant findings are as follows:

1. Ether anæsthesia caused an increase in the cardiac output in every instance. The mean blood pressure was slightly elevated during the anæsthetic.

2. Chloroform anæsthesia was associated with a definite decrease in the cardiac output and blood pressure in every experiment.

3. The changes during ethyl chloride anæsthesia were more variable, but usually consisted of a slight decrease in the cardiac output and blood pressure. Its effect was thought to be intermediate between that of ether and chloroform.

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EMPYEMA IN CHILDREN

A Preliminary Report

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IT has for many years been recognized that empyema in adults and empyema in children are in many ways dissimilar and as such present diverse problems to the surgeon and the physician. It is strange, however, that in the light of this knowledge many results of new and varied treatments have been reported without regard to the age of the patients involved. In some instances when a report on a series of children's cases has been made, no note is made of the definite age of the children involved. That this information is of the greatest importance is evidenced by the fact that the mortality from empyema is about four times greater during the first year than during the fourth.

It is the purpose of this paper to review a series of 371 cases of empyema in children and to study them with regard to age, year of incidence, and organism involved.

Of this group, 267 were treated in St. Mary's Free Hospital for Children during the years 1909–1927, and 104 were treated in the Children's Section of New York Hospital (First Surgical Division) during the years 1913–1927.

All cases recorded in this series were definitely diagnosed as empyema by aspiration and the roentgen-ray and all received surgical treatment. We have not included in this series a number of cases in which no surgical treatment was given, due to the condition of the patients, or cases which were found by autopsy to be empyematous after death caused by pneumonia.

The children treated at St. Mary's Hospital are for the most part from the poorer homes of New York City, the majority being of Italian parentage.

ETIOLOGY

Empyema in children is, as far as we can judge, always a secondary process usually arising from a previous attack of pneumonia. In our own series fully 92 per cent of all cases were either complications of or sequellæ to an attack of pneumonia.

Pneumonia	236
Chronic sinus	11
Bronchitis	8
Abscess of lung	1
Foreign body	2
Peritonitis	1
Tuberculosis	1
Undetermined	10

Apparently general hygiene and social status seem to have some bearing on the incidence of empyema in children. This is based not only on personal observation but on personal communications with a number of pediatricians.

The condition is not so commonly seen during the first year of life as during the 6 years that follow, probably because of the high mortality from pneumonia found in infants under the age of 1 year. During the season of 1925–1926 there was only a single child under the age of 1 year treated for empyema at the hospital. This child was infected with a nonhæmolytic streptococcus and recovered fully. During the same period of time there were 41 infants under 1 year treated for pneumonia. Of these 17 died, a mortality of 41.5 per cent.

Our figures are in agreement with those of Holt, who found the highest incidence from the condition during the second year.[1] From then on it gradually declines until the ninth year.

The mortality, however, was much higher during the first year of life than during any of the succeeding years. As is shown in Table I, the mortality during the first year was 66 per cent, whereas during the second year it dropped to 33 per cent. Holt in his series of 204 cases at the Babies Hospital, New York City, found a mortality of 71 per cent in children under 1 year, and 59 per cent in those

[1] Holt—Diseases of Infancy and Childhood, 8th ed., 544.

TABLE I.—AGE INCIDENCE AND MORTALITY

Year	Cases	Mortality	Mortality per cent
0–1	15	10	66
1	69	23	33
2	63	17	27
3	51	7	14
4	39	7	18
5	43	2	5
6	32	3	9
7	24	1	4
8*	10	1	10
9	3	0	0
10†	10	1	10
11	3	0	0
12	5	0	0
13	4	0	0
Total.....	371	72	19

*Patient was a Mongolian idiot whose case was complicated by bronchopneumonia, multiple lung abscesses, early pericarditis with effusion, parenchymatous degeneration of heart and kidneys. (Autopsy.)

†Patient was admitted and operated on for streptococcus peritonitis. Developed bilateral empyema on fifteenth day after operation. Then developed pericarditis and died of cardiac failure.

afflicted in the second year.[1] Wilensky of Mount Sinai Hospital, New York City, in a study of 200 cases, found a mortality of only 48 per cent during the first year and 31 per cent during the second year.[2]

After the second year the mortality rate steadily declines until about the age of 6 years. After that the deaths are seldom and usually result from some severe complication. The total mortality for our series of 371 cases was 19 per cent, there being 72 deaths. From the first and including the sixth year there was a mortality of 22 per cent. From the sixth to the fourteenth year the mortality was only 10 per cent.

It is of importance, however, to note that there is a wide variation in the mortality rate dependent upon the year during which the cases occurred. The percentage mortality varied from 0 per cent in the year 1922–1923 to 46 per cent in the season of 1925–1926 (Chart 3).

This marked variation is probably primarily dependent upon the virulence of the infecting organism, although there are other secondary factors such as the age of the patient and the specific infecting organisms. One might expect, since empyema most often follows pneumonia, that the mortality rates of the two conditions would show some relationship, because both conditions are usually caused by the same organism. The exact relationship between the two will be brought out in an article to follow on "The Cause of Death in Empyema in Children and Adults, a Comparative Study."

[1] Holt. Loc. cit., p. 545.

[2] Wilensky. Empyema of thorax. Surg., Gynec. & Obst., 1915, xx, 501.

TABLE II.—NUMBER OF CASES AND PER CENT OF MORTALITY FOR VARIOUS YEARS, SEASONS FROM JULY TO JULY

Season	Cases	Deaths	Mortality per cent
1915–1916	22	8	36
1916–1917	16	1	6
1917–1918	10	3	30
1918–1919	25	3	12
1919–1920	20	6	30
1920–1921	15	3	20
1921–1922	13	2	15
1922–1923	7	0	0
1923–1924	8	2	25
1924–1925	14	4	30
1925–1926	13	5	46

The condition is most prevalent between the months of November and June, as shown in Chart 4. For this reason we have arranged our years from June to June rather than from January to January, since the latter obviously splits an individual epidemic into two parts. An individual epidemic probably starts in October and continues to the June of the following year.

ORGANISM

The pneumococcus is the most common organism of etiological value found in empyema and carries with it a mortality of about 25 per cent. Table III gives the determinations made in a series of 134 cases.

TABLE III.—ORGANISM DETERMINATIONS IN ONE HUNDRED THIRTY-FOUR CASES

Organism	Cases	Deaths	Mortality per cent
Pneumococcus	73	18	26
Streptococcus	23	6	26
Staphylococcus	6	4	66
Mixed	12	5	42
Sterile	20	6	30

These have been classified according to the age of the patient in Chart 5. Although the number of cases so tabulated is to our mind insufficient, nevertheless several facts seem to be borne out. In the first place there is a marked difference between the pneumococcus cases during the first year and during the

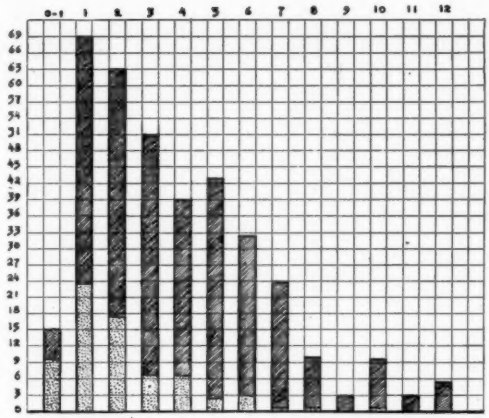

Chart 1. Age incidence of empyema in 371 children's cases. Stippled area indicates deaths.

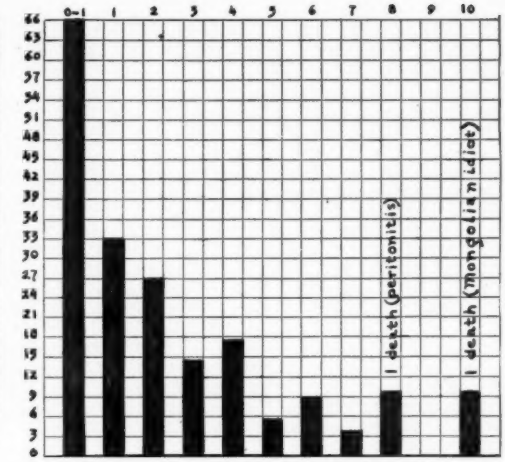

Chart 2. Mortality by ages in 371 children's cases.

years that follow. In the first year we find the pneumococcus responsible for only 22 per cent of the cases, whereas in the years that follow the number of pneumococcus cases averages around 60 per cent. This fact gains further weight when it is noted that the cases of pneumococcus empyema in children under the age of 1 year occurred during the same season (1919–1920).

On the other hand, during the first year, there is a much higher percentage in cases due to the streptococcus and to mixed infections. The latter is probably due to the fact that almost all pneumonias in children under 1 year are bronchopneumonias in type.

SEX INCIDENCE

In the 267 cases at St. Mary's there was a predominance of males over females. The mortality rate in males is also somewhat higher, as shown in the following:

	No. of Cases	No. of Deaths	Mortality per cent
Male	146	33	23
Female	121	21	17

The slight difference between the number of male and female cases in children bears a marked contrast to the condition as found in adults. In a series of 105 adult cases from the First Surgical Division, New York Hospital, we found more than two-thirds of the cases in men. A comparative study of these cases and our children's series will be included in a future article.

LOCATION

Of the 267 cases from the records of St. Mary's Hospital, 155 were on the left side, 105 were on the right side, and 7 were bilateral. Of 161 cases during the last 10 years, the following figures were obtained:

	No. of Cases	No. of Deaths	Mortality per cent
Left	96	23	24
Right	63	10	16
Bilateral	2	2	100

COURSE OF DISEASE

The most common symptoms found are the continued fever after the previous illness, the dyspnœa, cough, and the condition of anorexia and general malaise. In some cases pain on respiration is found over the affected side.

Empyema can be easily diagnosed by a combination of physical signs, aspiration, and the roentgen-ray. In several cases there was difficulty in diagnosis until roentgenograms were made, as the empyematous cavity was situated between two lobes of the lung at some distance from the chest wall. The average temperature during the acute process ranges from 101 to 104 degrees F. In some cases it ran above these figures and in some below.

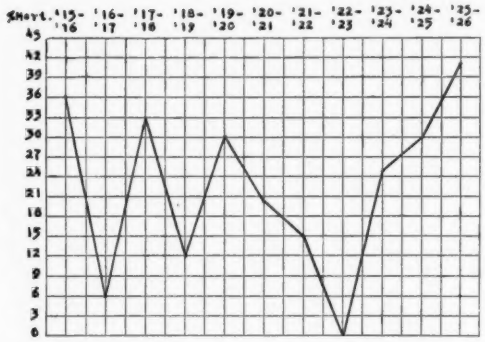

Chart 3. Report of cultures in 134 cases of empyema in children.

A study of the leucocyte and differential count presents the most bizarre figures. One hundred and four cases give total counts ranging from 6,000 to 83,000, with an average of 34,000. The one patient with a count of 6,000 and the two patients with counts of 11,000 died. One of those with a count of 11,000 had miliary tuberculosis. The average count for fatal cases was 35,000, practically the same as the general average. Sixteen counts of 50,000 or over are recorded, 7 of them in fatal cases.

Of the differential counts the lowest was 34 per cent, the highest 98 per cent. The average was 74 per cent. The average count in the fatal cases was 78 per cent. The highest count in a fatal case was 98 per cent, the lowest 55 per cent. It will be seen that no prognostic deductions can be made from the total leucocyte or differential counts. All the figures point to a great intensity of infection.

The hospital stay ranged from 12 to 155 days with an average of 62 days after rib resection and 51 days after intercostal incision.

TREATMENT

In all cases the first measure taken was aspiration. This was done not only to drain the pus but also in order to determine the nature of the fluid. In the very early cases with thin fluid, aspiration was continued until conditions favored open drainage. In only 3 cases was aspiration the only treatment, all of the patients dying. They were very ill and operation would probably only have hastened the end.

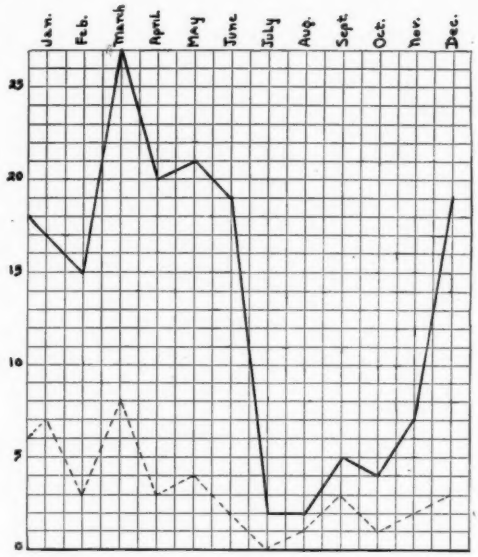

Chart 4. Seasonal incidence. Report on 159 children's cases. Solid line indicates cases; broken line, deaths.

In all other cases open drainage was used. Of 226 cases in which operation was performed, resection of ribs was resorted to 168 times with 30 deaths, 18 per cent. Intercostal incision with open tube was used 58 times with 19 deaths, 33 per cent. The high mortality found with the intercostal incision is due to the fact that it was frequently used when the patient was too ill to undergo general anæsthesia and the shock of a rib resection. That it is not so severe as the figures might indicate is shown by the fact that the mortality rate of the cases in which operation took place at the hands of one of the surgeons who uses only intercostal incisions is comparatively low when compared with that of the other operators who rely chiefly on rib resection.

No case was treated by trochar tube nor by aspiration followed by antiseptic injections. Dakin's solution has been used without especially brilliant results simply to cleanse the open cavity. With rare exceptions, the fright caused in children has seemed to outweigh the advantages. It is a debatable question also whether digestion of the pleural surfaces is a wise measure in acute cases.

Binney in 1924 reported a series of 100 cases treated with closed drainage, of which 35 were in children from 1 to 10 years old. Of these there were 5 deaths, or a mortality of 14 per cent.[1]

In our series there were 359 patients under the age of 10, of whom 72 died, a mortality of 20 per cent.

In spite of the scarcity of cases presented by Binney, his results are, to say the least, of great interest. It is of importance, however, to know the ages of the patients so treated, the mortality for the various age groups, and the year or years in which the cases occurred.

Ladd and Cutler report a series of 42 cases in which there were 12 deaths, a mortality of 28 per cent.[2] Although they do not give the age groups, they state that the majority of the deaths occurred in infants in whom the mortality would have been high anyway. The figures in Table IV may be of interest concerning the relative merits of the open and closed method.

TABLE IV.—RELATIVE MERITS OF OPEN AND CLOSED METHODS

	Cases	Deaths	Mortality per cent	Secondary Operations No.	Secondary Operations Per cent
St. Mary's Hospital and New York Hospital (open)	371	72	19	12	3
Binney (closed)	35	5	14	21*	..
Ladd and Cutler (open)	226	36	15.9	10	4
Ladd and Cutler (closed)	42	12	28	21	50

*Of 100 of all ages.

ANÆSTHESIA

Of 150 cases operated on between 1916 and 1927, ether was used 138 times with a mortality of 16 per cent. Novocain was used 10 times with a 60 per cent mortality. The figures are as follows:

TABLE V.—ANÆSTHESIA

	Cases	Deaths	Mortality per cent
Ether	138	22	16
Novocain	10	6	60
Ethyl chloride	1	0	..
Chloroform	1	0	..

[1] Binney. Study of one hundred cases of empyema treated by a closed method. Boston M. & S. J., 1924, cxci, 1206–1214.

[2] Ladd and Cutler. Am. J. Dis. Child., 1921, xxi, 546.

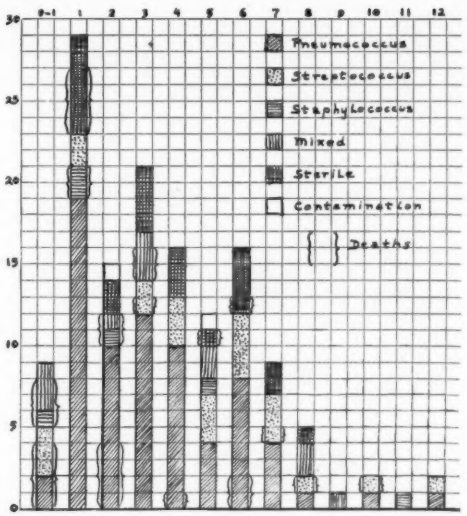

Chart 5. Percentage of mortality from empyema in children during the years 1915–1926.

The above statistics are of little value inasmuch as the cases in which novocain was used were often of such a serious nature that general anæsthesia could not be used.

A study was also made of the mortality by operators during the years from 1916 to 1927. In this series are included only operators with 10 or more cases (Table VI).

TABLE VI.—MORTALITY BY OPERATORS

Operator	Cases	Deaths	Mortality per cent
Dr. U.	10	5	50
Dr. V.	16	5	31
Dr. W.	23	6	26
Dr. X.	17	3	18
Dr. Y.	26	4	15
Dr. Z.	22	1	5

These figures are of little significance unless the following points are taken into consideration:

1. The tendency for certain operators to do only the more severe cases and let the internes do the others.

2. The seasons during which the operators were on service. (It is of interest to note, in this connection, that all the cases in which Dr. V. operated occurred during 6 months of a year when the mortality rate was high.)

SEASON	O-1	1	2	3	4	5	6	7	8	9	10	11	12	13	TOTAL
'15-'16	s	OP IIII	III	P II	O II	O S+P S+P II	OO II	I			I				22
'16-'17		SP IIII		P III	P I	I s I	I	I	I		S*				15
'17-'18	S	P I		P O I I	O P I I	O P I I	P III								13
'18-'19	s I	O P P II	P P I	P P P IIIII	P P O M IIII	P S I		P III				s I	I		23
'19-'20	P P I	POPPO IIII	PO II		S S I		O P P II	O P I		M I			S I		20
'20-'21	M M I	P s I	P I	M P P O III	P I		P	P I	M P I					P I	15
'21-'22		P I	O I	S NH P O I I	S I	S I		S I			P I				9
'22-'23			P I	O I		P S I	S P P P IIII								8
'23-'24		P P I	s P I		P I	P I	S I								7
'24-'25	S NH	P I	M P I	P P I	P P I	S NH I	S P I	P I	S				P I		14
'25-'26	S NH I	POPS III	P P I	P I		P I		S S NH I							12
TOTAL	10	31	18	26	16	15	17	12	4	1	3	1	3	1	158

*PERITONITIS

Chart 6. Age, organism and mortality by year of 158 acute cases. *P*, pneumococcus; *S*, streptococcus; *s*, staphylococcus; *O*, sterile; *M*, mixed, *NH*, non-hæmolytica.

3. The year during which the operations were performed.
4. The age of the patients.

Dr. Y. used only the intercostal incision.

COMPLICATIONS

Complications are frequent in empyema. Blocking of the exit is really an incident rather than a complication, but it occurs very commonly and must be kept in mind when any untoward symptom develops. Pocketing is also fairly common but in children is usually simple, easily detected, and as easily remedied. Aspiration of the tube is occasionally seen. A rare accident is the unrecognized loss of part of the tube within the chest cavity. A roentgen-ray or fluoroscopic examination should be made at not too long intervals. The opposite chest can thus be kept under observation also. Osteomyelitis of the rib occurs in a small proportion of the cases, rather less in the intercostal type. Again the roentgen-ray is of the greatest assistance in detecting the presence and extent of the trouble. Necrosis of the rib is a fairly common cause for persistent sinuses and local pocketing. It rarely produces a late recurrence.

Acute anæmia of varying degree is a constant complication of empyema. Repeated red cell counts and hæmoglobin estimations should be made. The judicious use of blood transfusions is to be commended.

It may also be remembered in this connection that in drainage of the cavity, the child is losing a great deal of body fluids as well as body proteins. It is therefore necessary to force fluids and to give plenty of nourishing food. Bell has figured that adults lose as much as 21 grams of nitrogen per day.[1]

The complications which occurred in 168 cases at St. Mary's Hospital during the years (1916 to 1927) are as follows:

[1] E. A. Graham and R. D. Bell. Some principles involved in the treatment of empyema. Surg., Gynec. & Obst., 1920, xxxi, 60.

	Cases		Cases
Otitis media	12	Erysipelas	2
Pneumonia of same side	11	Peritonitis	2
Pneumonia of opposite side	8	Nephritis	2
Bronchopneumonia	8	Pericarditis	2
Lung abscess	6	Scarlet fever	2
Pneumothorax	4	Gangrene of lung	1
Tonsillitis	3	Osteomyelitis of rib	1
Furunculosis	3	Banti's disease	1
Tuberculosis	2	Chicken pox	1
		Measles	1
		Gastro-enteritis	1

PROGNOSIS

The prognosis seems to be dependent upon a number of factors. The most important of these are age, complications, virulence of organism, condition of patient, and treatment.

We have already shown the relation of age and virulence of the organism to the mortality, and have pointed out the complications that occurred. It is of interest to note, however, that of 33 deaths occurring at St. Mary's between the years 1916–1927, 29 were complicated by serious conditions. Nineteen of these were sympneumonic, 3 were complicated by lung abscesses, 3 by peritonitis, and the remainder by such conditions as pericarditis, gangrene of the lung, furunculosis, and acute nephritis.

It would appear that the cases having resistance sufficient to outlast the first onslaught of infection and to localize it, become surgical possibilities. Our mortality seems to be a measure of the intensity of the infection and the onset of severe complications. This is suggested by the postoperative day of death.

The average period of life in fatal cases was 15 days after operation. In the cases in which death occurred during the first 3 days, in almost every instance the condition of the patient had been very poor at the time of operation. Deaths at a later period than this were usually due to severe complications.

In our series of cases there seemed to be little relationship between the time from the previous illness to the diagnosis of empyema and the mortality. It is probable that the thickened pleura which was found in a number of the fatal cases has some bearing on the final prognosis, but in all cases it seemed to be of only secondary importance.

So far as the surgical treatment is concerned, the most important factor is the knowledge of when to operate. Operation before the pus is thick and the cavity well walled off increases the gravity of the prognosis to a marked degree.

CONCLUSIONS

1. Empyema is a complication in nearly all cases of a persisting and serious disease.

2. The incidence of empyema varies as regards age, year, season, and organism. It probably bears a relationship to the prevalence of pneumonia and to the virulence of the affecting organism.

3. The mortality in infancy is very high. From then on it drops rapidly until the age of 7 and remains extremely low in adolescence and early adult life. Age seems to be the most important factor but the type of infection, the year, and the virulence of the organism also have a great bearing on the prognosis.

4. It appears from the figures obtained that the time between the preceding illness and the diagnosis of empyema is only of secondary importance as regards prognosis, the main factors being the virulence of the organism and the general condition and resistance of the child.

5. Death from empyema in children is in almost all instances due to a general condition of debility brought on by the previous illness or due to existing complications and not to the empyema itself.

6. The various methods of treatment now in use—the use of the intercostal incision or rib-resection, open drainage or closed drainage, Dakin's solution or simple drainage—seem to have little influence upon the prognosis.

7. The time of operation following the diagnosis of empyema depends entirely upon the individual case and the surgeon should be guided by the nature of the pus and the general condition of the patient.

8. Recurrences seldom result if free drainage has been obtained and maintained until the closure of the wound.

DISCUSSION

DR. HOWARD LILIENTHAL: Attention should be called to the importance of a proper estimate of the gross pathology in cases of empyema. It is not

scientific to consider a case of suppurative pleurisy as represented by a single cavity. The cause of empyema is usually infection from the surface of the lung and this may start from more than one focus. Indeed, I have operated in many cases in which by free intercostal incision with ocular examination it was possible to identify several, in one case as many as 5, different pockets each having apparently risen from a separate focus, and no two alike as to the character of the exudate, varying from seropus to thick pus. Indeed, multiple empyema cavities were fairly common and frequently the different sacs contained different organisms. However, I have found that as a practical method, the primary treatment by trocar and cannula with the insertion through the cannula of a small multifenestrated rubber catheter, about 14 F., with a very soft finger cot valve attached, would in about one-third of the cases result in a complete recovery without injection or lavage of the thoracic cavity. The cannula is removed, leaving the catheter in place. The soft finger cot is then tied firmly to the end of the catheter outside the chest and finally a generous slit is made in the end of the finger cot. With every expiratory effort, fluid, with or without air, is forced out while on inspiration the sides of the finger cot are sucked together, preventing air or fluid from entering the chest.

If the course of the convalescence is uninterrupted the exudate gradually becomes serous and when X-ray examination demonstrates full expansion of the lung then the tube can be withdrawn. If, however, there is continued fever or other signs of sepsis, an X-ray examination should be made after 5 or 6 days and other loculi of pus, if discovered, should be treated by more radical surgery.

OBSERVATIONS ON THE INTRAMURAL AND ISTHMIC PORTION OF THE FALLOPIAN TUBES WITH SPECIAL REFERENCE TO SO-CALLED "ISTHMOSPASM"

Based on Clinical X-Ray Lipiodol Study and Utero-Tubal Insufflation in 50 Cases of Tubal Occlusion

By I. C. RUBIN, M.D., F.A.C.S., New York

SINCE a method of localizing tubal obstruction has been found, increasing attention has been given to the narrowest portion of the fallopian tubes, which traverses the uterine musculature at either cornu. It is but natural to assume that this portion of the oviduct, measuring as it does from 0.5 to 1 or at the most 1.5 millimeters in diameter might be occluded readily by inflammation and intra-uterine tumors, or temporarily obliterated by uterotubal spasm. As its function is to offer passage to the young impregnated ovum, the presence or absence of anatomical anomalies and inflammation is of some importance in a consideration of the etiology of sterility. Certainly from a theoretical point of view, spasm of the tubes, particularly if its incidence can be proved to be as high as has been claimed, must also be a causative factor.

Several publications have appeared recently dealing with the anatomical and pathological study of the intramural portion of the tube, notably those of Hermstein and Neustadt (5) and of Geist and Goldberger (4). The conclusions of both papers are based upon skiagraphs made of injected, extirpated specimens of uterus and tubes. The specimens were removed because of fibromyomata alone, of bilateral disease of the adnexa, or a combination of the two. Emphasis was laid upon the *tortuosity*, angulations, and convolutions of the intramural portion in these cases—a condition which occurred, according to Hermstein's and Neustadt's report, in 54 per cent out of 15 specimens examined. Geist and Goldberger in confirming these findings in the anatomical material go farther in their conclusions, as applicable to problems in sterility. They claim that in an appreciable number of cases of sterility, the tortuosity of the tubes at their exit from the uterine cavity as found in the extirpated specimen is responsible for the high pressures reached during clinical utero-tubal insufflation. They maintain this to be a cause of obstruction to spermatozoa, and leave the impression that this condition is a factor in sterility more commonly than has hitherto been recognized. Other clinical deductions made by them are based upon their anatomical study.

Of the specimens studied by Hermstein and Neustadt, 9 were resurrected from among specimens which had been immersed in formalin solution for some time, and the remaining 6 were removed from the fresh cadaver. Mercury was used by them in the injections. The specimens studied by Geist and Goldberger were removed by operation, injected with 20 per cent sodium iodide solution and skiagraphed before being immersed into formalin. The latter authors believed that they were dealing with "living" organs because of their fresh state.

There can be no question as to the importance of these anatomical studies as such, or of the careful and painstaking work reported by these authors. But the interpretation of their findings and conclusions, because of their clinical implication, may be subjected to further scrutiny:

1. Neither the formalinized specimen nor the so-called "fresh" specimen maintains the functional conditions found in the living, intact organ or in the *surviving* extirpated organ. The uterus and tubes removed at the operation, unless properly preserved in suitable oxygenated solutions, die rapidly and undergo the changes of rigor mortis. It is a common observation that tubes become markedly contracted and thicker as soon as they are removed from the body. The tube lumen can thus become more sinuous, especially at the intersti-

tial portion where the powerful muscle is in contraction. *The pictures of the intramural portion of the fallopian tubes obtained in the living are entirely different from those shown in the dead state.* Comparison with the shadowgraphs of uterus and tubes made by early personal clinical studies with collargol, thorium, and sodium bromide (13) brought out the difference in a striking way. Shadowgraphs of the myomatous uterus and tubes when removed from the body, however, presented a tortuous appearance of the intramural portion (14).

2. The tortuosity in the injected specimen as R. L. Dickinson (2) has pointed out, may be due to artificial conditions, such as pressure upon the specimen exerted during the injection. Dickinson expresses the opinion that the tortuosity might not have been found if the specimen were immersed upside down in water and the uterine cavity injected while an even water pressure surrounded the uterus. It will be recalled that in the living the uterus is suspended by its ligaments and during injection the intra-abdominal pressure is equally distributed over its surface and uniformly maintained so that there can be no eccentric pressure in any one portion. In myomatous uteri, moreover, the distortion may be due to the encroachment of the tumors upon the uterine cavity particularly when they are situated near the horns.

3. Experiments upon the surviving uterus and tubes of the pig (20) and also upon these organs in the human subject (1) have shown that under suitable conditions muscular contractions can be conserved for from 1 to 3 hours and their behavior is quite analogous to that of the living intact organs. It has seemed, therefore, as if a truer picture of the intramural portion of the tubes would be presented by injecting the uterus clinically. As fibroids and gross pathological disease of the tubes, such as bilateral pyosalpinx, are too plainly involved in the etiology of female sterility and as the second of these two conditions contra-indicates the use of carbon dioxide insufflation or even lipiodol, they were excluded from the present study.

In this study only those cases of sterility were selected in which the tubes had been previously demonstrated by repeated test with peruterine insufflation to be totally occluded or markedly stenosed. It was felt that in this class of cases the possibly deleterious effects from lipiodol injections would either be avoided or if present, would at least be minimized. Although more complete physiological data could be obtained in the study of normally patent tubes, it appears better for the present, and until a perfect contrast medium is available, to restrict our study to more or less occluded tubes. Lipiodol was selected as the contrast medium because it has so far proved to be the most satisfactory of all the radio-opaque substances employed. It should be borne in mind, however, that the injection of lipiodol may be followed by untoward sequelæ. In the present series, for example, the latter were encountered 4 times out of the 50 cases examined.

When the tubes are occluded at the fimbriæ, the appearance of the intramural portion can be studied in the living exactly as in the extirpated specimen, because in this instance instead of a ligature being tied about their abdominal ends, nature has sealed them by adhesions of internal occlusion.

In the 50 cases examined by means of lipiodol injections and the X-ray, the tube has been found *to emerge from the uterine cavity in a straight course* in almost every case in which the tube shadow appeared on the film (Fig. 1). An L-shaped course, so common apparently in anatomical specimens, was observed but once and that in an elderly nullipara on the side showing a hydrosalpinx (Fig. 2). Obviously this abnormality cannot be held responsible for the obstruction in this case. The intramural portion was naturally absent in those cases in which the entire tubes had been removed at the laparotomy. Of the 50 cases the interstitial portion was seen 32 times, 1 or both tubes being present. In 16 cases they were absent because of previous surgical removal of both tubes.

Injected with lipiodol.	
Showing both tubes	17
Showing one tube only	13
Showing neither tube	18
Showing bilateral short tube stumps	1
Showing unilateral short tube stump	1
Total number of cases	50

Total absence of tubes.

History of previous laparotomy for pelvic diseases.	12
History of no operations	3
History of previous dilatation and curettage	3
Total number of cases	18

One tube only.

History of previous laparotomy for pelvic diseases.	4
History of no operations	5
History of previous dilatation and curettage	3
Total number of cases	12

In a case with bilateral short stumps of tubes, no operation was done.

In a case with unilateral short tube stump, no operation was done.

Both tubes.

History of previous laparotomy (not pelvic)	6
History of no operations	8
History of previous dilatation and curettage	3
Total number of cases	17

4. The frequency of intramural closure by anatomical aberration or inflammation according to Geist and Goldberger, although no figures of the number of specimens examined by them are given, is apparently so great as to make it a matter of much importance in sterility. They report: "In about 40 per cent of the cases it (the intramural portion) passes in a gently direct curve with the convexity upward through the wall of the uterus until it emerges. Occasionally it rises in a steep curve more or less abruptly from the uterine funnel. In the remaining cases the course is not a simple direct one, but tortuous, either traversing the uterine wall in a series of gentle convolutions up to four in number, or in a course marked by decided angulations either one or two in number. In the angular course, the tube usually rises sharply from the uterine cone to within a few millimeters of the peritoneal surface, then sharply bends down again until it emerges occasionally just before, or at, its point of departure from the uterus it again makes a sharp angle giving it an L-shaped point of exit or other bizarre forms." Also: "We found frequently a definite œdema of the mucosa with an infiltration of round cells and increased vascularity, resulting in sufficient swelling and thickening of the mucosa to cause some obstruction." Peterson (11) states that this portion of the tube is singularly free from infection. The latter was present in but few instances out of thousands of sections of tubes studied in his laboratory.

In all the 17 cases of the present series in which both tube outlines appeared in the roentgenograms, the intramural portion was seen to be clearly patent and in all but 1 a straight course was observed. Of the 13 cases in which only one tube outline was present, the interstitial portion was very faint in 4 cases and probably constricted by disease which practically obliterated the lumen of the whole tube as only an irregular outline was observed when considerable pressure was used in the lipiodol injection. In 1 of these 4 cases I had an opportunity of observing the tubes. This patient who had never been operated upon before and whose tubes were sealed off by a single post-partum infection, was keenly desirous of improving her chances for conception. It was seen that the isthmic portion of the right tube was completely obliterated, while the left isthmus was very markedly narrowed (Fig. 3). It was possible to transplant the patent ampulla of each tube into the corresponding horn of the uterus. Patency in this case was demonstrated later by periuterine insufflation.

In the 33 cases in which no tubes or only 1 tube appeared on the film after lipiodol injection, 16 gave a history of previous abdominal operation; in 6 others a dilatation and curettage had been performed at some time. In 11 cases no history of an operation was obtained. What rôle infection may have played in obliterating the lumen of the tubes in these cases, can only be surmised. An analysis of such factors from the history presented will be taken up elsewhere. Here it is important to call attention to the fact that in the 2 cases in which 1 or both tube stumps were present, the intramural portion was demonstrable and showed a straight course indicating that the disease most probably involved the isthmus. It is a matter of conjecture, in the absence of observations possible only at a laparotomy, as to how many of the 17 cases in which the tubes were not removed by operation were obliterated *in toto* or along the isthmic portion alone. Further observations and a larger series of cases may settle this question. It appears from the evidence at hand, that the isthmus is far more commonly diseased than the intramural portion of the fallopian tubes.

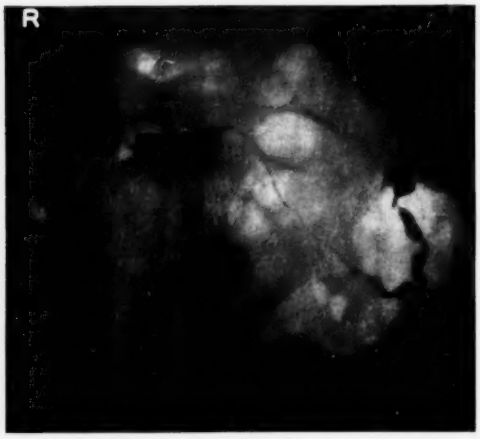

Fig. 1. Roentgenogram showing emergence of the tube lumen from the uterine horn in a straight course. Left tube showing peristalsis at the ampullary portion. Note the unusually long left tube.

Fig. 2. Roentgenogram showing tube taking L-shaped course as it emerges from the left uterine horn. Unusual finding in clinical lipiodol injections.

Two factors appear to account for the relative infrequence of inflammatory obstruction in the intramural portion of the tubes: (1) The scant endosalpinx with 3 or 4 folds which are relatively widely separated, in contrast to the rich supply of tubal plicæ of the ampulla, which if inflamed become readily agglutinated; and (2), the more powerful muscle of the interstitial portion would tend to expel products of inflammation when present in the direction of the wider portion of the tube or toward the uterus. In this connection it may be recalled that if inflammation of the interstitial portion of the tube were at all common, the incidence of tubal pregnancy in this location would be excessive while as a matter of record, interstitial tubal pregnancy is the least frequent of all ectopic pregnancies.

Narrowness of the intramural portion *per se* therefore does not appear to be a handicap from the viewpoint of procreation for which nature seems to have provided adequate safeguards. The tube, moreover, has the power of dilating to allow the passage of the ovum. In the pig, the ovum reaches the blastula stage on the third day when it passes into the uterus. A more striking dilatation of the oviduct is seen in the hen in which a large ovum, the mature hen's egg, traverses the tube and uterus and passes out of the cloaca. If this be true for the ovum, it would seem, at least, to hold equally well for spermatozoa.

ROENTGENOLOGICAL AND FUNCTIONAL DIVISIONS OF THE TUBE

From roentgenological studies, the tube may be divided into two main portions: (1) a narrow proximal, uterine portion and (2), a wider distal, abdominal portion. The length of the fallopian tube, as revealed by salpingography is greater than is apparent on inspecting it at the operating table or in anatomical examinations. In the living state, it frequently measures 6 or 9 inches as against the 3 or 4 inches which it measures when removed from the body (Fig. 1). This extended length of the tubes in the roentgen films may be due to a straightening out of the tube lumen through the force of the injected fluid. Magnification of the picture on the film is very slight.

The narrow portion or oviduct proper has almost the same caliber from its beginning just outside of the uterus to about half its entire length where the wider portion abruptly begins. The narrow portion is only slightly

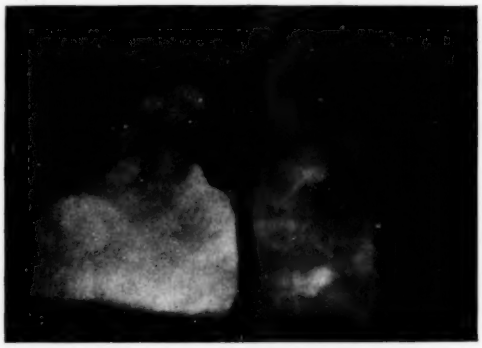

Fig. 3. Roentgenogram showing isthmic portion of right tube completely obliterated. Left isthmus markedly narrowed; therefore not appearing on the film.

Fig. 4. Roentgenogram showing absence of isthmus shadow on left side. Same case as illustrated in Figure 1 in which the entire isthmus is beautifully shown (serioroentgenogram).

narrower as it passes through the uterine wall, where its mucous membrane is thrown into primitive folds which have a trifoil or cloverleaf shape to a star or H-shape on cross section. This portion outside of the uterine wall is palpable as a whip cord between the fingers, the sensation imparted being due to the presence of re-enforced circular muscle. Unfamiliarity with this anatomical fact has led to misinterpretations and to useless operations. Kennedy (6) believed he was dealing with closed tubes in one case because "the isthmus felt as though it contained a 'fibrous core' on both sides. It was decided that they were the seat of obstruction. They were excised and a hysterosalpingo-anastomosis was done which rendered the tubes patent and relieved the dysmenorrhœa, but not the sterility. Carbon dioxide insufflation by Aldridge had previously shown these tubes to be normally patent. Serial section of the excised isthmus showed them to be normal."

The wider portion or receptaculum ovuli feels much softer between the fingers and begins about at or near the middle of the tube. It is provided with numerous mucus folds which lie almost contiguous and present on cross section a labyrinthian appearance. The abdominal end opens up in a somewhat constricted lumen from which radiate the fimbria. This, however, will for example permit the passage of a uterine cannula in contrast to a fine filiform bougie which can scarcely be introduced into the intramural portion. In the lower animals, as the pig, the fimbria ovarica is thinned out and broadened into an enveloping membrane which covers the ovary almost completely, thus securing a more successful reception of the ovum as it is cast off and by peristalsis pushed well on through the ampullary portion. The outer end of the tube has been termed the pars fimbrica and the uterine end the pars uterina.

THE QUESTION OF ISTHMOSPASM

The difference in anatomical structure between these 2 portions is parallel with their physiological difference. If the tubes of the pig are observed in peristalsis, it will be noted that the narrow portion which is nearer the uterus undergoes more pronounced contractions than the outer end.

In the presence of a foreign body such as lipiodol, the human fallopian tubes may be seen to undergo peristalsis beginning at the ampullary portion and traveling toward the uterus. Reversed peristalsis is not uncommon. The contractions appear to be more powerful at the isthmic portion. The narrow portion is not so easily visible under the fluoroscope as it has the width approximately of a coarse hair. That accounts for its apparent absence in some cases. Kennedy (7) found this absence of isthmus shadows in 38.3 per cent of the tubes he examined with sodium bromide solution and the X-rays. He therefore concluded: "Inasmuch as the ampulla of the tube ren-

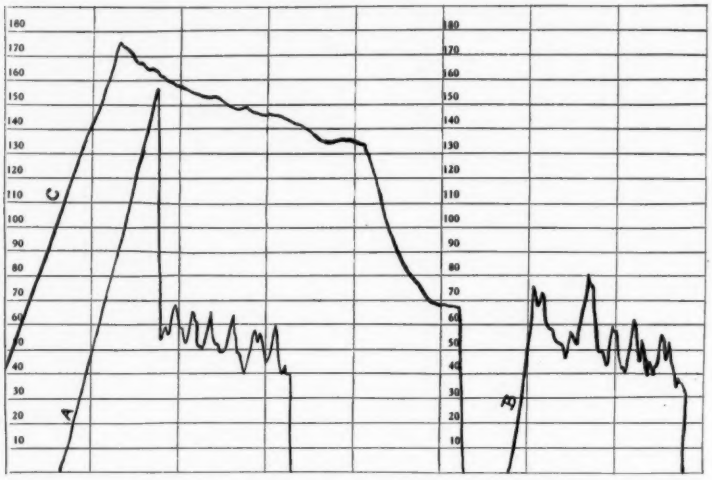

Fig. 5. *A*, Kymographic record of case of spasm at the tubo-uterine junction. Note the sharp rise to 155 millimeters mercury and the sharp drop to 55 millimeters mercury, after which the kymographic curve is normal as can be compared with curve in *B*. *B*, Kymographic tracing in a normal tubal patency. Initial pressure rise to 75 millimeters mercury, fluctuations between 35 and 20 millimeters mercury in depth.

dered a shadow, it must be connected with the uterus by a patent isthmus even though the passage between contains no sodium bromide." A second case of an isthmus of the tube removed by Kennedy led him to believe that a tubal isthmus appearing microscopically normal can have a patent canal and yet be obstructed. "Doubtless more such tubes exist and the isthmus while anatomically normal, has a physiological abnormality of the hypertonic circular muscles." In his conclusion Kennedy states: "A tube having an apparently normal ampulla and no evident abnormality of the isthmus even though it obstructs the passage of carbon dioxide gas by insufflation, should not be removed at operation, because we may render a patient permanently sterile who is now only temporarily so." Therefore, Kennedy concludes that the isthmus must have been in spasm.

In a recent study in which the question of isthmospasm was considered, it was seen that Kennedy's conclusions were based upon observations which were misleading because of technical difficulties only recently overcome. These may be briefly stated:

1. The isthmic portion of the tube is exceedingly narrow as has been pointed out. Unless a very opaque substance is used, the shadowgraph may not be intense enough to be seen. Sodium bromide is much less dense than lipiodol for example. Lipiodol is denser than bone shadow, but the latter obscures sodium bromide especially when it overlaps a fine line such as the isthmic lumen.

2. F. Kok (8) claims that sodium bromide proves irritant to the pelvic peritoneum. Dyroff and Schober also maintain that it irritates the tubal and uterine mucosa, therefore inciting more violent muscular contractions than are provoked by substances such as lipiodol. In one instance ulceration of the bladder has been reported (Kok).

3. Blurring of the isthmus is easily produced when the patient moves or does not hold her breath. Immobility is essential. The intra-uterine injection of the fluid should be made with the patient lying on the X-ray table. The focusing of the visual field is very important. Fluoroscopic visualization is of great help in getting the proper focus and condensing the field to be X-rayed. In this procedure a well trained radiologist should be associated with the gynecologist.

My study was greatly facilitated by the cooperation of A. J. Bendick (6 and 7). We

found that the isthmus was demonstrated in every instance in which the tube had not been previously removed by operation, or was not obliterated by disease. In one instance the isthmus was seen by the fluoroscope but not on the X-ray film. This meant that the lipiodol had been discharged simply into the abdominal end of the tube or back into the uterus and out. The fluid is not only rapidly emptied from the isthmus, but as its lumen is very narrow at best, too little is left to render a contrast shadow. If serial roentgenograms are made, it will be found that the isthmus will appear on the X-ray plate at one moment and not at another. This does not, however, indicate isthmospasm in the sense that pyloric spasm, for example, is generally understood. It is simply the contraction phase of normal peristalsis (Fig. 4).

Arnstam and Reinberg brought this out (12) in a recent serial roentgenological study of the uterus and tubes with the aid of lipiodol (metrosalpingography). If intra-uterine pressure with the fluid is maintained, the isthmus will be seen each time, because peristalsis is paralyzed by the distending fluid. When the pressure is slight or even moderate, peristalsis returns and the isthmus as well as the ampulla exhibit contractions. Because of its narrow lumen, the isthmus will not cast a shadow on the film unless a very densely opaque substance is used, and the exposure is taken in the dilating phase. Its lumen on the other hand is wider at times than at others, showing that it is capable of dilatation. If the patient is examined with the fluoroscope a few hours after the initial lipiodol injection, it will be seen that the closed ampulla is filled, while the isthmus is empty. The ampulla remains filled with lipiodol for weeks and months, the fluid accommodating itself to the more dilated portion of the tube where it rests because of weak or totally absent peristalsis.

That there may be an augmented tonicity of the isthmus tubæ as well as of the whole tube, may be readily granted. In studying tubal patency by means of peruterine insufflation and the kymograph, it has been seen that sometimes the initial pressure required to overcome the resistance at the uterotubal junction and the isthmic resistance, may be as high as

Fig. 6. Roentgenogram showing gap in tubo-uterine junction on the right side (sphincter action). Contrast this with appearance of left horn where the tubo-uterine junction is dilated.

200 millimeters mercury. Once this has been overcome the flow of the gas is freer and there is a steady drop as the undulations appear on the recording drum and in the manometer (Fig. 5, a). This occurs in a small proportion of the cases examined. Contractions of the tube vary in strength between 5 and 30 or 40 millimeters mercury. Exceptionally, the manometer fluctuates between 70 and 90 millimeters mercury. Fluctuations are noted on the drum soon after the gas passes the uterotubal junction and are recorded in practically every normal case. The presence of manometric fluctuatious distinguishes the normal tube in hypertonicity from a strictured tube, or one which is diseased and bound down by adhesions. In the latter case, if the tube is not absolutely occluded, the gas may succeed in passing at a high pressure and after a drop find a level at which it continues to flow as long as the gas pressure is maintained. But there will be a complete absence of fluctuations in the manometer and of corresponding undulations on the kymograph (Fig. 5, c).

THE FREQUENCY OF INCIDENCE OF TUBAL SPASM AS A CLINICAL ENTITY

Observations of many cases in which the question of tubal patency was determined indicate that the incidence of tubo-uterine spasm is not very frequent. It occurred about

9 times out of 450 cases, in which the examination was made with a kymographic attachment. That is, the tubes were found to be patent after an initial high pressure (150–190 millimeters mercury) was required to force the gas through them. It has been pointed out elsewhere (15) that in the premenstrual and menstrual stages of the ovulation cycle, higher pressures were necessary than in the post menstrual phase. Ferdinand C. Lee (9 and 10) showed that in some of the laboratory animals it was always easy to inject from tube to uterus, whereas, when an injection was made in the reverse direction—from uterus to tube—the injection mass would pass with much greater pressure through the tubo-uterine junction. But when the animal was found to be near the time of ovulation, the injection mass would pass more readily requiring less pressure. The tubo-uterine junction is apparently guarded by a sphincter apparatus analogous to the pyloric sphincter, although as in the latter, no definite muscle bundles have so far been demonstrated (Fig. 6). Personal experiments with gas insufflation in the living animal and upon surviving extirpated specimens of intact uterus and tubes point to a definite very small zone corresponding to the intramural portion of the tubes which is capable of contracting and dilating like a true sphincter. Reinberg and Arnstam have described it, and recently Schmidt and Eisler have independently raised the question as to whether there is a sphincter apparatus at the tubo-uterine junction (18). The present series of lipiodol studies corroborates their findings. (This will be taken up in the near future.)

CONCLUSIONS

The intramural portion of the fallopian tube in the living pursues a straight course contrary to what is found in the anatomical specimens. It is capable like the rest of the tube of contracting and dilating. Total obliteration of its lumen is very infrequent and when present is part of more extensive tubal disease. "Isthmospasm" as an entity has not been definitely demonstrated but tubal contractions can be seen with the aid of intra-uterine lipiodol injection and the fluoroscope. The uterotubal junction (intramural portion) appears to be the site of predilection of spasm or hypertonicity in a relatively small proportion of the cases examined. It was demonstrated by uterotubal insufflation with the aid of the kymograph in 2 per cent of 450 cases of sterility. It can also be demonstrated by fluoroscope and X-ray film aided by lipiodol and manometric control. A sphincteric action at the tubo-uterine junction has been evidenced in clinical and experimental observations.

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CLINICAL SURGERY

FROM THE LEYSIN INSTITUTE OF HELIOTHERAPY

HELIOTHERAPY IN HIP JOINT TUBERCULOSIS

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THE cures obtainable by heliotherapy are distinguished by three principal characteristics: a splendid general condition, development of the musculature, and frequent return of function in diseased joints. This last result is of particular interest in tuberculous hip disease; and for this reason we shall devote our main attention to this form.

Believing that in tuberculosis, the question of the soil is of capital importance, while the bacillus plays a secondary rôle, we have recommended from the beginning of our work, general heliotherapy, that is to say, the methodical insolation of the total surface of the integuments. We have also arrived at this conclusion because we believe that the skin in not only an organ of protection but also a very important organ of defense. It plays a leading rôle in the general metabolism, and is able to subserve its physiological functions only when placed in direct contact with its natural *milieu*, air and sun.

Proceeding from these principles, we have applied, since 1903, general heliotherapy to so-called surgical tuberculosis; and we have sought to build up a real therapeutic system based on a precise posology and associated with a rational orthopedic technique which broke with the traditions hitherto accepted. Heliotherapy of this kind in association with the air bath, for which the altitude is particularly suitable, stimulates admirably the natural defenses of the organism, and brings about its complete reconstitution, while at the same time providing the ideal local treatment, thanks to the analgesic, resorptive, and sclerosing properties of the solar radiations.

The action of the sun is first of all general and manifests itself on all the systems, the skin, the musculature, the blood, the endocrine organs, and the skeleton itself.

The skin, when placed in contact with the air and sun is toned up and pigmented: it regains its many physiological functions and becomes once more the real garment provided by nature. Thanks to the fine mesh of capillaries, alternately dilating and contracting, it forms by this expansion of the vascular system, a "peripheral heart." Through its multiple nerve endings for touch and pain, it also becomes another expansion of the nervous system. The skin is also the "vicar of the kidney," secreting as it does more than one liter of sweat per day, with sebaceous matter and various toxic substances. It is, furthermore, the most important source of immune bodies; probably also the most important endocrine organ.

Skin, when pigmented, and thus physiologically adapted to heat and cold, resists the penetration of germs; the cicatrization of wounds is thus favored; and such a skin is refractory to many cutaneous affections. The pigment serves not only as a protection against over irritation by the ultraviolet rays but also as a regulator of the sun's heating power. It probably plays an even more important part; it is supposed that it acts as a kind of accumulator of dynamic forces; and our experience tends to confirm this view, inasmuch as a patient's resistance is generally proportionate to his pigmentation. It becomes, indeed, increasingly evident that the skin receives, furnishes, and activates the essential elements for the metabolism of hormones and vitamines; and it is probable that the majority of the avitaminic conditions are simply due to lack of sun.

The action of the sun on the musculature is very remarkable. By dilating the skin capillaries, it causes a flow of blood from the depths to the surface, thus acting as the most perfect massage. The building up of the muscles under the influence of the sun may be attributed doubtless to this more active circulation and also to the continuous reflex tonic action on the muscular fiber arising from the vibratory shock of the radiations on the mesh of sensitive nerve endings in the skin.

By restoring to the muscles and ligaments their natural tone, the sun-cure re-establishes the normal balance of this lever mechanism and thus by an eminently physiological process, brings about the return of articular function.

The sun's action is exercised not only on the muscles but on the bones. We have about 50,000 X-ray plates which prove beyond question that no lesion, however deeply situated, remains insensible to the solar radiations. The first sign of cure in bony lesions is recalcification; but this recalcification of the bony skeleton is not peculiar to tuberculosis; it is a commonplace in the treatment of rickets and of other bony dystrophies. We drew attention to this property from the beginning of our work in 1903; and the question has of late years been studied by many authors, particularly Hess, of New York, and his collaborators, Paffenheimer and Ungern, who have demonstrated an increase in the calcium and phosphorus of the blood under the action of light. This remineralization of the organism is contemporaneous with a steady increase in the percentage of hæmoglobin and of the number of red blood corpuscles. Further the sun-cure, especially in mountain air, causes an increased respiratory activity, which improves the heart action and the general circulation. The metabolism is increased, the appetite awakened, the digestive functions invigorated; and the strength is recovered. Finally, heliotherapy has a favorable action on the internal secretions due to the stimulation of the endocrine glands by the solar radiations.

While then general heliotherapy can restore to the body undermined by tuberculosis a normal physiological function and a symmetrical harmony, its local action is of equal importance in the treatment of bone tuberculosis and particularly in hip disease. The solar radiations are analgesic. Pain rapidly diminishes and finally disappears under their influence combined with that of a suitable extension. The resorptive power is shown by the fact that peri-articular œdema and infiltration steadily decrease; and finally their cicatricial action is proved by the recalcification of bone evident on the X-ray film. The sun has also a valuable cleansing action on sinuses, and by its bactericidal action rapidly heals the most obstinate and chronic wounds. It is of fundamental importance to remember that heliotherapy will not give such valuable results if it is used haphazard.

A rigorous dosage and strict technique are primary essentials. We have established certain principles of posology applicable to all cases which are of such importance that I feel compelled to state them briefly. Dosage must be so graduated that the reactions produced by the solar radiations in the organism are never of harmful intensity. This requires of the doctor an active control and a strict individualization (careful examination of each case on arrival; slow, gradual adaptation, first to the open air and then to the sun; careful study of the general and local reactions which may occur during treatment and which are for the doctor the most valuable indications for the further progression of insolation, etc.).

On arrival, a case of hip disease is immediately relieved of his plaster apparatus. After a few days of repose and acclimatization, immobilization and extension are begun. In some cases extension must be applied immediately after removal of the plaster to combat pain and tendency to dislocation. The patient remains at first in his room with the windows open, where he accustoms himself gradually to the altitude. Then if he shows no general reaction attributable to climatic condition (e.g. rapid pulse, subfebrile temperature, nervous excitability, etc.) his bed is rolled out on the balcony to accustom him to the open air. After a period, which depends for its length entirely on the observations of the doctor (general resistance of the patient, state of his organs, presence or absence of secondary infection, with or without elevation of temperature, etc.) the sun-cure proper can be started.

The reaction of the organism to the sun, both local and general, varies with each patient and it is essential to regulate the sun-bath according to the individual indications. The optimum duration of insolation in each case is easily determined by careful observation. We have nevertheless drawn up a simple schema, to serve as a general guide. The main principle is, in every case, to start with the lower limbs. This is an obviously rational precaution, for by exposing first the legs and feet, a "neutral" region which can be insolated without danger, one can measure the degree of the patient's tolerance of the sun, and thus acquire, at the start valuable indications for the continuation of treatment. This method by causing a flow of blood to the lower limbs has a marked decongestive action on the thoracical and abdominal viscera. Our long experience has taught us that by the correct use of heliotherapy as above described even the most advanced cases run risk of accidents.

The first exposure to the sun is therefore very brief. On the first day, the feet are exposed 3 times for a period of 5 minutes each with a half-hour interval between exposures. On the second day, the feet are given 3 periods of 10 minutes each and

Fig. 1. Patient suffering from tuberculous hip disease with sinuses; showing apparatus of extension and how the work-cure is practiced with the sun-cure.

the legs 3 times of 5 minutes up to the knee. The following day: 3 times of 15 minutes for the feet, 3 times of 10 minutes up to the knee, and 3 times of 5 minutes to the hips. On the fourth day the abdomen is exposed to the sun; and the fifth day the thorax with a damp cloth protecting the precordial region. The upper regions of the body should be exposed with great prudence. During this time the condition of the patient, his temperature, pulse, and particularly the local reactions, are carefully observed, and at the least sign of intolerance the periods of insolation are shortened or momentarily suspended. This schema is of course susceptible of variation in accordance with the patient's degree of resistance, his sensitiveness, or nervous temperament. It is essential to individualize and vary one's methods for each case, if good pigmentation is to be obtained in the minimal time without accidents. Insolation of uninfected tuberculous hip joints, for instance, demands a quite different procedure than do those cases in which infected abscesses (not cold abscesses) and sinuses are present. In the latter type, local reactions are common with rise of temperature and abundant suppuration; such reactions are often injurious when they are too acute; and they must be kept within bounds, or in some cases completely avoided. This demands careful individualization, guided by an instinct which is only acquired through experience. When the body starts to pigment, insolation of each region may be doubled and the patients exposed to the sun for several hours. Experience has, however, proved that it is useless and sometimes dangerous to prolong the sun-bath immoderately: generally speaking 3 hours a day is a reasonable average. During hot weather the sun should be taken in the early morning hours to avoid overheating, which both congests and exhausts the organism.

Heliotherapy alone cannot of course bring about the cure of hip disease with correction of orthopedic deformity. Rational orthopedics must be used as an adjunct. The following principles form the basis of our orthopedic practice. In the first place we have broken with the old tradition of which the main dogma was the closed plaster apparatus. From the beginning of our work, we considered the wearing of such apparatus to be in contradiction with true physiology and orthopedics. These impermeable shells by depriving the diseased region of air and sun destroy the local resistance at the very place where it is most needed. Their use causes rapid atrophy of the integuments; atrophy of the musculature, which is indispensable for the return of articular function; and atrophy of the bony skeleton inasmuch as decalcification of bone is favored by lack of sun, accentuated in this case by the toxic decalcification of tuberculosis. We have replaced the fixed

A *B*

C *D*

Fig. 2. *A*, Roentgenogram of patient with severe tuberculous coxitis showing migration of the acetabulum, perforation of the acetabulum, faulty position. *B*, Cured, with trabecular structure forming a firm barrier between head and small pelvis. *C*, Photograph of patient showing vicious attitude. Mixed infection. *D*, Same patient to show the application of our extension apparatus; cured after 2 years.

plaster shell by orthopedic appliances of great simplicity of which the main principle is the free access of sun to the diseased regions thus aiding the local defense without hampering the general treatment.

For hip disease, just as for Pott's disease, the correct arrangement of the bed is the touchstone of orthopedic treatment. The mattress should be flat and of hard material, sufficiently resistant to avoid forming hollows under the pressure of the body as a soft mattress into which the body sinks prevents normal evaporation of sweat, favors the maceration of the skin, and the formation of bedsores; it may also cause faulty position.

The bed we use is of metal with an under frame of steel plates. It is furnished with wheels to allow of its being rolled on to the gallery and is sufficiently high to facilitate the careful control of the position of the pelvis and the extension apparatus and at the same time permit of free exposure to the sun. A millet seed cushion is placed on the hard mattress to raise the pelvis, a very important point in the treatment. This raised position, while steadying the pelvis facilitates perfect exposure to the sun of the coxofemoral region; it is further largely instrumental in preventing flexion and adduction deformities, or in correcting them if already present on arrival. Continuous extension of the leg on the diseased side is an absolute rule of treatment. Its object is to hold apart, by axial traction the articular surfaces, so as to prevent friction and adhesion with contact contamination of the opposing surface. By this separation of the articular surfaces, it helps the analgesic action of the sun. The extension should pull from the thigh to avoid distension of the knee joint. Formerly we used "manchettes," or cuffs made of leather, attached, one above the knee and one at the ankle and joined by leather straps to which the extension weights were slung. These cuffs, however, were found to have a slight tendency to atrophy the muscle, and we have now replaced them with long strips of sticking plaster reaching up to the trochanter.

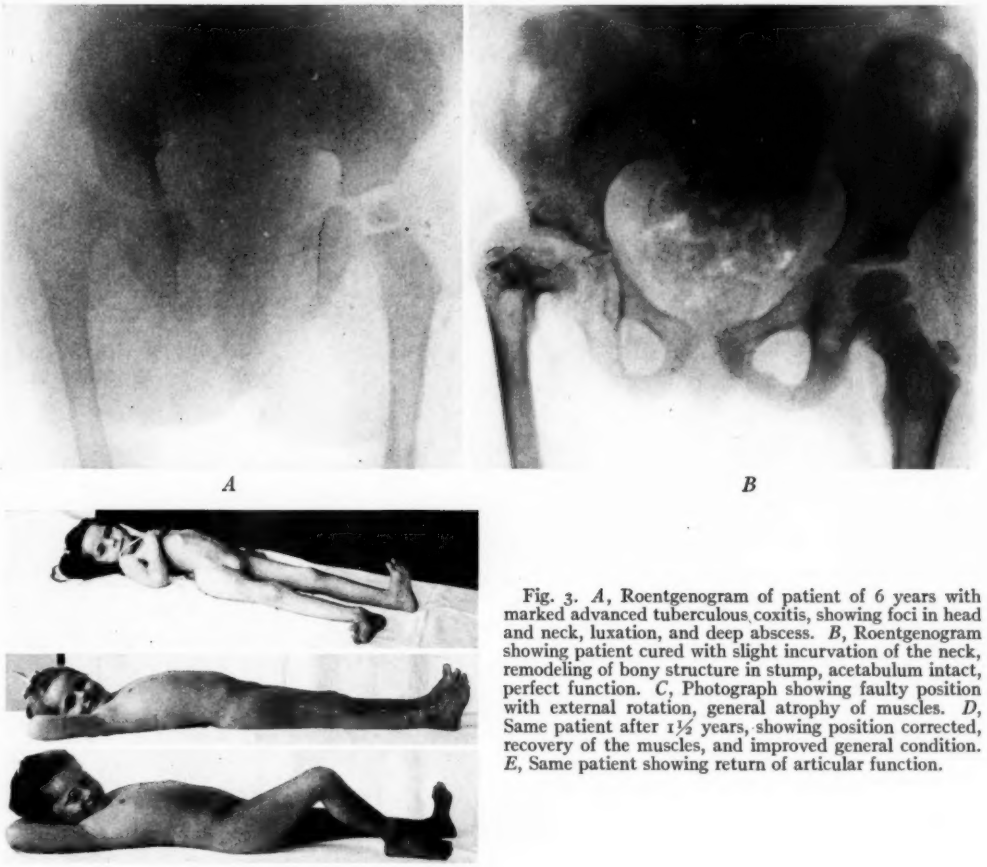


Fig. 3. *A*, Roentgenogram of patient of 6 years with marked advanced tuberculous coxitis, showing foci in head and neck, luxation, and deep abscess. *B*, Roentgenogram showing patient cured with slight incurvation of the neck, remodeling of bony structure in stump, acetabulum intact, perfect function. *C*, Photograph showing faulty position with external rotation, general atrophy of muscles. *D*, Same patient after 1½ years, showing position corrected, recovery of the muscles, and improved general condition. *E*, Same patient showing return of articular function.

To facilitate the extension, and to get the full unhindered pull of the weight applied, we use a back splint of aluminium or perforated celluloid on which the leg rests. This is posed on a fixed static and is fitted with small wheels which run in grooves. We thus avoid the friction of the heel on the bed, and the extension loses none of its force. When the pelvis is tilted, extension is applied to the other leg, thus re-establishing the equilibrium. Where combined abduction and extension is required, we use an apparatus in which the aluminium back splint with its static is, in turn, posed on another static, on which it is freely movable in a lateral direction. By applying a lateral weight extension to the back splint, abduction is thus combined with extension. In some cases in which deviation is very marked, a rubber tube padded with gauze is passed through the opposite groin, and the two ends fixed to a pully extension at the top corner of the bed.

In many cases of hip disease, the malposition of the hip joint is accompanied by a tendency to equinism of the foot. To combat this we use a special sandal with a wide sole which is fixed over the instep: two elastic bands running from the toe of the sandal to above the knee, are put more or less on the stretch according to the degree of equinism. This apparatus in no way interferes with the mobility of the foot, which it gradually brings back to correct position. For children and restless adults it is advisable to apply a thoracic brace of strong canvas, which acts as a counter extension and insures a more complete immobilization. It is fitted with shoulder straps and buckles. This brace which can easily be opened to allow of general insolation is firmly fixed to the

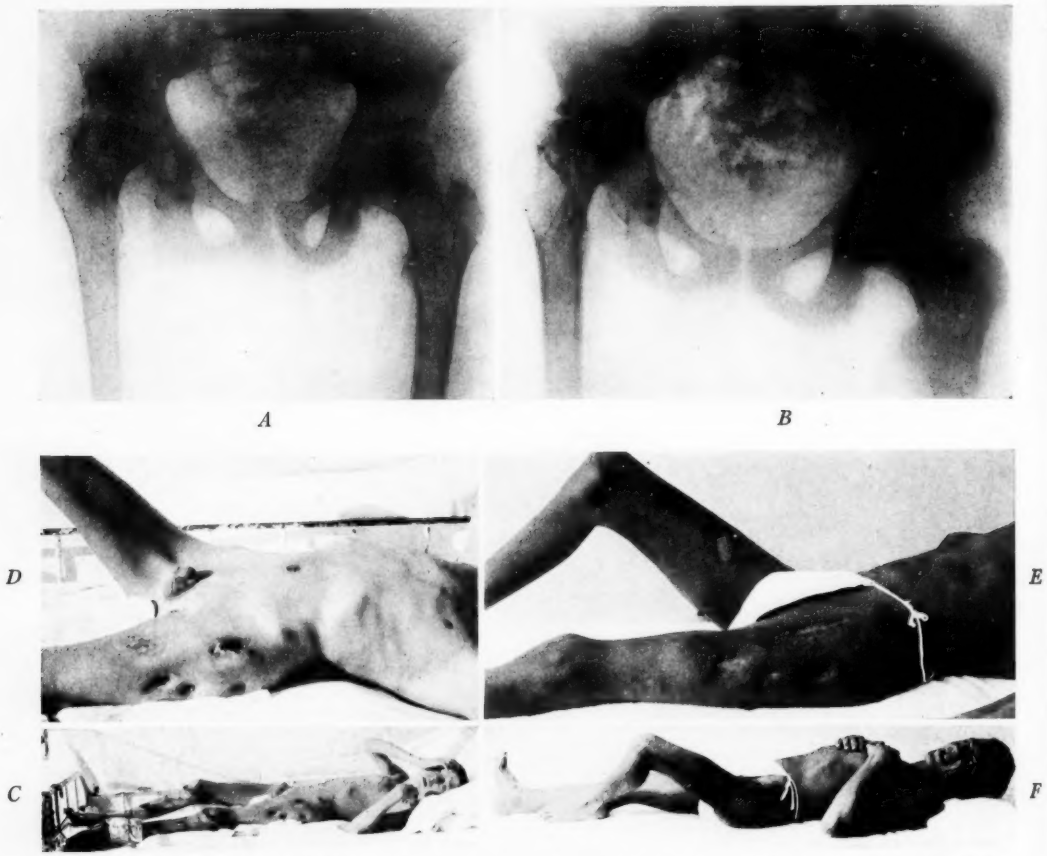


Fig. 4. *A*, Roentgenogram showing loss of head, spread of disease through floor of acetabulum into small pelvis, marked atrophy, and bony structure effaced in bad, old case of tuberculous coxitis with mixed infection. *B*, Marginal sclerosis of the acetabulum, remodeling of the stump with new contour, firm calcified structure, communication with small pelvis firmly closed. *C*, Photograph of patient, and *D*, detail on arrival. *E*, Same patient after 21 months: disease arrested, striking improvement of the general condition, and *F*, partial return of function.

bed. It is applied as a general rule to all children suffering from hip disease. If it is considered necessary, the pelvis can be more securely immobilized, and at the same time undue pressure on the abdomen avoided, by means of a simple broad elastic band passed round the hips and laced at the side. Straps furnished with buckles fix this band to the two sides of the bed, and thus assure strict immobilization and satisfactory equilibrium of the pelvis.

One of the first results of the sun-bath, in association with a rational orthopedic technique, is the disappearance of pain which manifests itself after a short time. Even after the first few days it is well known that the famous "coxitis cry" is heard no more. This analgesic action must be attributed to the decongestive action of the sun on the deeper regions, aided, as we have seen above, by the extension of the leg. Improvement of the general condition of the nervous system and of the whole organic resistance under the influence of the sun and air bath also contributes largely to the diminution of pain. One must never forget that the patient's morale, which is so important a factor in the cure, is powerfully stimulated by the marvellous sensation of well-being which the daily practice of the sun and air bath produces. We are often spectators of a real

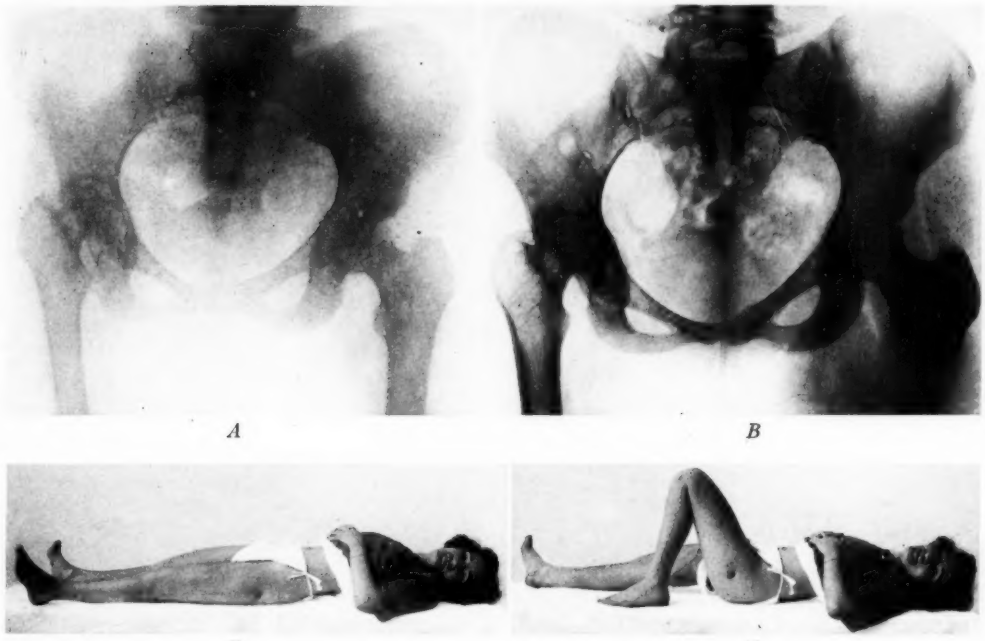


Fig. 5. *A*, Roentgenogram showing migration of the acetabulum, contours of the head and of the acetabulum eroded, enormous atrophy in tuberculous coxitis with sinus. *B*, Reappearance of trabecular structure, complete demarcation, interarticular space clearer. *C*, Photograph of patient. *D*, Normal function after 20 months.

psychical renaissance in our cases of surgical tuberculosis and among them the sufferers from hip disease. This reaction certainly hastens the progress of the cure, and forms a valuable aid for the doctor, who must in all such chronic troubles combine a knowledge of psychotherapeutics with his other attainments.

Another precious aid for the morale of the patients is the "work-cure," which can be practiced regardless of the weather, and which experience has taught us to value as a real therapeutic agent. In the profound conviction that rigorous and complete immobilization is an error prejudicial to the organic defenses, we sought by introducing a progressive course of manual work, strictly individualized, to develop the specific resistance of each patient contemporaneously with his general resistance.

It may seem somewhat paradoxical at the first glance to propose manual work for cases of surgical tuberculosis often seriously ill and always confined to bed. Our experience, however, has been that graduated regular work under medical control has never in the least hindered the progress of the cure. On the contrary it is a real help for cases of hip disease. A special apparatus enables the patients to work lying on the back without any danger of the least unsuitable movement of the hip joint which is held by the running extension. They can thus easily learn weaving, filet, crochet, painting on wood or on porcelain; while patients with Pott's disease, in the ventral position are able to undertake wood cutting, box and basket making, typewriting, and the manufacture of minor mechanical objects. The advantages of this work cure, when carried out systematically are indisputable; it is the most powerful antagonist of boredom—the common danger in all chronic diseases; and it provides poorer patients with an appreciable financial aid. A tuberculous subject once capable of undertaking remunerative work loses the depressing feeling of uselessness, regains a sense of his social worth, and thus enters on the first stage of his return to normal life.

As soon as the clinical and radiological condition of the hip joints permits of moderate mobilization without fear of accident, the patients are

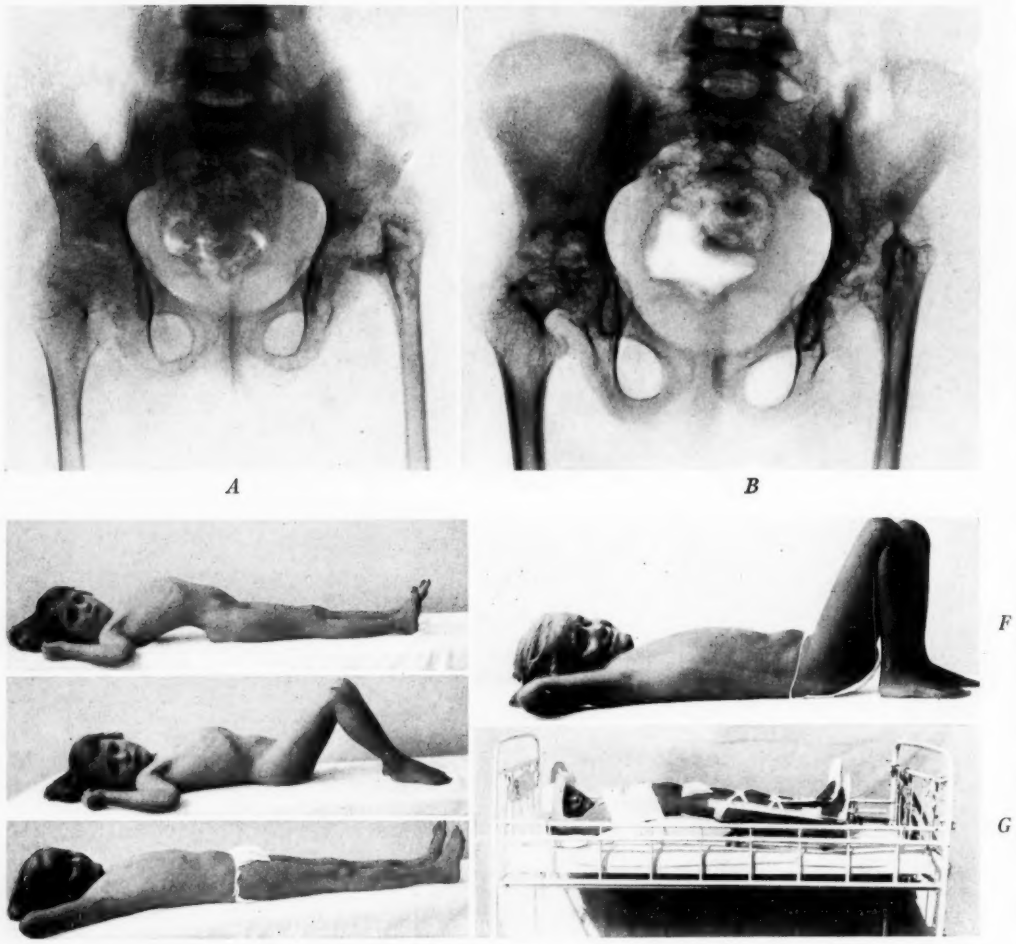
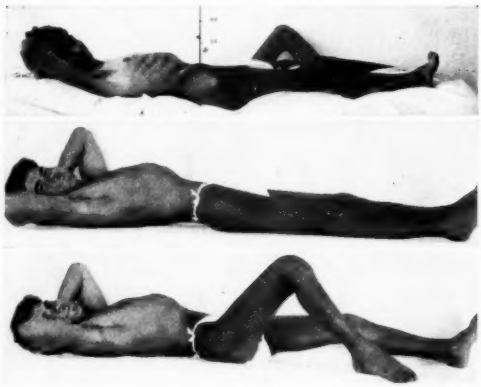


Fig. 6. *A*, Roentgenogram showing disease in full activity, advanced destruction, loss of head and neck, luxation, on other side epiphyseal focus; deep abscess, in case of bilateral tuberculous coxitis. *B*, Complete arrest of the disease and cure; solid trabecular structure and very satisfactory demarcation of the remaining bone. *C*, Photograph of patient on arrival, showing marked compensatory lordosis. *D*, On arrival, incomplete function. *E*, Cured after 2½ years. *F*, Photograph to show complete return of function. *G*, Showing double extension apparatus.

placed in the ventral position for a part of the sun-bath. A wedgeshaped cushion is placed under the thorax and another under the feet to avoid excessive traction on the toes. The ventral position does not exclude the maintenance of extension, and it has the great advantage of allowing exposure of the whole body to the sun, particularly the thigh regions, and thus helping the development of the musculature. Often a real muscular regeneration is the result. The quadriceps so often degenerated to mere strips and the gluteal mass, completely flattened out, inelastic, and bereft of all power regain a form and size approaching the normal. As the circulation becomes more active and intense under the action of the sun and with the renewed participation of the integuments in the circle of local metabolism, so the muscles recover their tone and elasticity and contribute to the return of articular function. This return of function as we have

A B



C D E

Fig. 7. *A*, Roentgenogram of patient with tuberculous coxitis, showing luxation after migration of the acetabulum; head of femur completely dislocated forms indefined cloudy mass. *B*, Roentgenogram showing readaptation of head to the displaced acetabulum which is firmly sclerosed, cicatrization of head; satisfactory function. *C*, Photograph of patient showing vicious attitude, cachexia, disease neglected. *D*, Cured after 2 years. *E*, Complete return of function.

already pointed out is quite common in the cure of hip disease by heliotherapy. It is, however, always spontaneous: we never allow active movement of the joint by the patient, nor do we ever attempt passive movements. To nature belongs the task of restoring function so far as she judges it possible and free from danger. The beginnings of movement are seen during treatment and develop *pari passu* with the progress of cure. But only after the X-ray has demonstrated the cicatrization of the bone do we allow the patient to try occasional flexion movements which improve the circulation and strengthen the muscles. By daily repetition of these small flexion movements, one helps the restoration of mobility to the joint in so far as the anatomical condition permits.

I must admit that in the early years at Leysin impregnated with the teaching of my master, Professor Koch of Berne, whose assistant I had the honor of being for 4 years, I was surprised and somewhat disturbed to see return of function following cure by heliotherapy. I was, however, reassured by the examination of X-ray films, showing a magnificent bony reconstitution of the affected articulations; and later we were able to convince ourselves that hip disease cured by heliotherapy with recovered movement had much less tendency to relapse than when cured with ankylosis. In the beginning, this return of mobility seemed to us so abnormal and uncertain that we thought it necessary to fix the healed joint with an unjointed celluloid apparatus. This we soon abandoned, realizing, on the one hand, that the apparatus tended to atrophy the fine musculature of our hip cases, and, on the other hand, that the return of function was both solid and durable. One must attribute this mobility to a combination of the following factors: the improvement of the circulation and of the local defense under the action of the sun, the building up of the musculature which is stimulated to more active metabolism by the actinic rays and which thus reacts much more easily on the bony levers as soon as the joint is capable of movement; and finally to our system of orthopedics which by condemning

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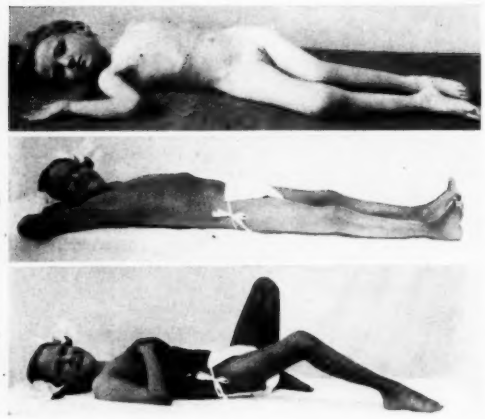

C

D

E

Fig. 8. *A*, Roentgenogram of patient with bilateral tuberculous coxitis, with luxation, showing acute condition with luxation, on one side perforation of the acetabulum. *B*, Cure with slight displacement on one side, all bony tissues are firmly cicatrized and show good structure. *C*, Photograph on arrival. *D*, Patient cured after 20 months. *E*, Photograph to show return of function.

the plaster cast eliminated straight off the principal cause of functional impotence. In addition, heliotherapy by diminishing the frequency of abscesses and their complications, the secondary inflammatory reactions, e.g., œdema, sclerosis and thickening of the soft parts, vascular atrophy, etc., provides a further aid to the return of articular function. Treatment of hip disease by heliotherapy is most successful when the lesion is a closed one. In the presence of a cold abscess, contrary to the generally accepted practice, we are in no hurry to aspirate. We wait as long as possible, i.e., as long as the abscess does not threaten to open spontaneously. Aspiration is carried out when the skin, thinned by the abscess, demonstrates that nature has no further use for it and is seeking to get rid of it. We attach a great importance to the presence of these cold abscesses, which, by their content in immune bodies, contribute a valuable immunizing factor to the defense of the organism. Aspiration is carried out at a distance, and is repeated if necessary to prevent spontaneous opening. Experience has taught us that the complication of mixed infection completely reverses the favorable prognosis of closed hip disease. And for this reason, we insist on conservative treatment of this localization which avoids transforming a closed into an open tuberculous lesion.

In fistulous hip disease, the essential condition for cure is above all to assure good drainage. If the track is well drained the sinuses dry up *pari passu* with the improvement of the general condition. If, on the other hand, drainage is insufficient, periods of retention are frequently accompanied by high temperature, discomfort, anorexia, and pain, all of which have their effect on the general health. When these attacks are followed,

Fig. 9. *A*, Roentgenogram of patient with severe tuberculous coxitis with sinuses, showing melting of all articular structure, perforation of acetabulum, and large abscess around the articulation. *B*, The whole articulation is strengthened and cicatrized and readapted to almost normal function with as strong bony partition as *point d'appui*. *C* and *D*, Condition of patient on arrival. *E* and *F*, Patient cured after 2 years. *G*, Showing return of function.

as it is often the case, by a pus-debâcle, recovery is rapid. This is, however, not so when the pus is incompletely evacuated and, remaining in the tissues, causes serious intoxication, which may ultimately lead to amyloid degeneration. To prevent an inopportune closure of the sinus openings with the danger of retention, the sun is applied in small doses and damp compresses are afterward laid on. In the sinuses with a deep track, a wick of sterile gauze is inserted, or laminaires to prevent premature closure. Generally the sun, by virtue of its strongly detergent and eliminative action tends at first to increase suppuration. It then diminishes, becomes serous, purulent, and finally dries up altogether when the general and local condition is sufficiently restored. In some serious cases of fistulous hip disease with multiple sinuses and deep abscesses the procedure indicated is not sufficient to prevent retention, inasmuch as the horizontal position impedes the drainage through openings situated in front or often even in the iliac fossæ. To facilitate drainage, in such exceptional cases only, we feel justified in allowing the patients to get up before complete cure of the bony lesion, and we permit them a little graduated exercise on crutches. In such cases the bad leg hangs freely without the aid of any supporting appara-

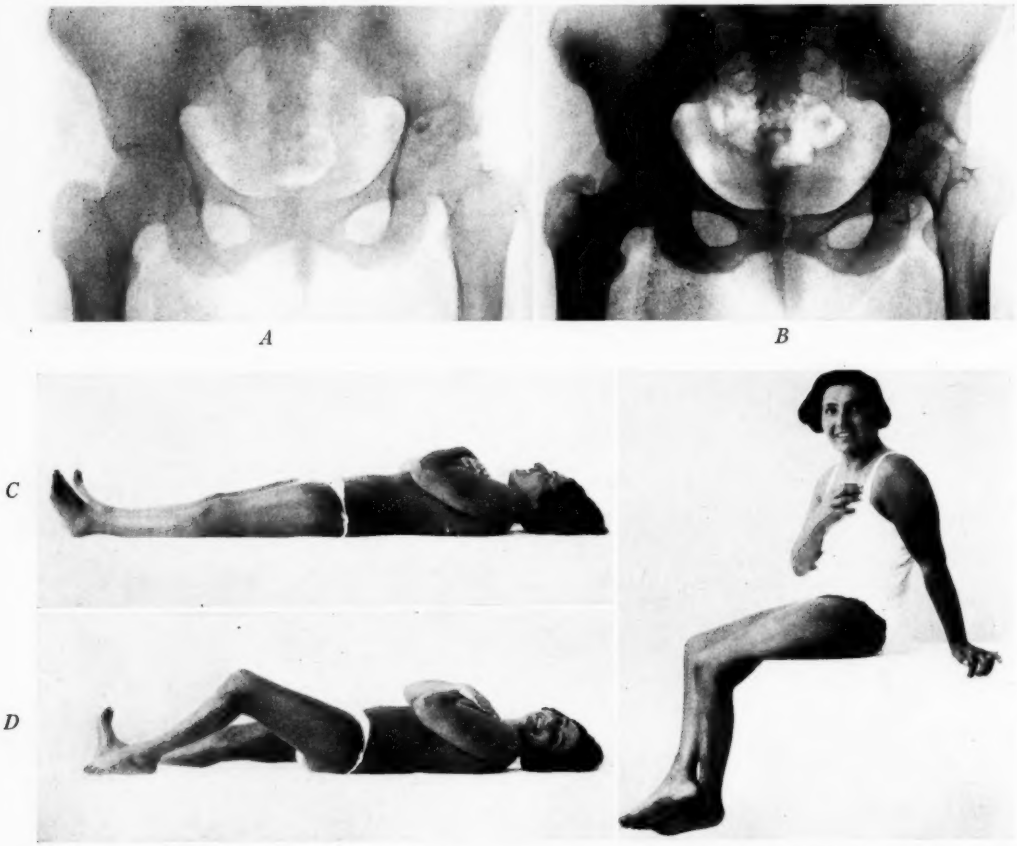

Fig. 10. *A*, Roentgenogram of patient with tuberculous coxitis, showing foci in head and neck with formation of sequestrum. The whole region is a cloudy mass without clear contour. *B*, Cure with reappearance of contours of the head and neck, reorganization of sequestrum and solid marginal sclerosis of acetabulum. *C*, Photograph of patient cured after 2½ years. *D* and *E*, Photographs of same patient to show return of articular function.

tus which might cause pain or impede the circulation, and the sound foot is raised in an orthopedic boot. We have often succeeded by this change in facilitating the evacuation of pus, recovery from intoxication, return to a regular temperature curve, and consecutive improvement of the general and local condition. As a general rule, we do not allow our cases of hip disease up until X-ray examination, confirming clinical findings, has demonstrated complete sclerosis of the lesions.

Some 50,000 X-ray films have been taken here since the beginning of our work and we have had ample opportunity to observe that no bony lesion however deep, escapes the influence of the solar rays. In hip disease, bony reparation and reconstitution occur in the following way. We commonly see tuberculous cases in full activity with the acetabulum, the head, and even the neck of the femur showing the signs of extensive melting, represented on the film by the well-known fog which obliterates the contours of the joint. In this chaos a new head gradually reappears, of which the outlines, at first confused and cloudy, become gradually more precise and regular. The demarcation zone becomes clearer and the decalcified regions are the seat of intense recalcification. In other cases in which the femoral head had burst through the caseating floor of the acetabulum, the X-ray films demonstrate recon-

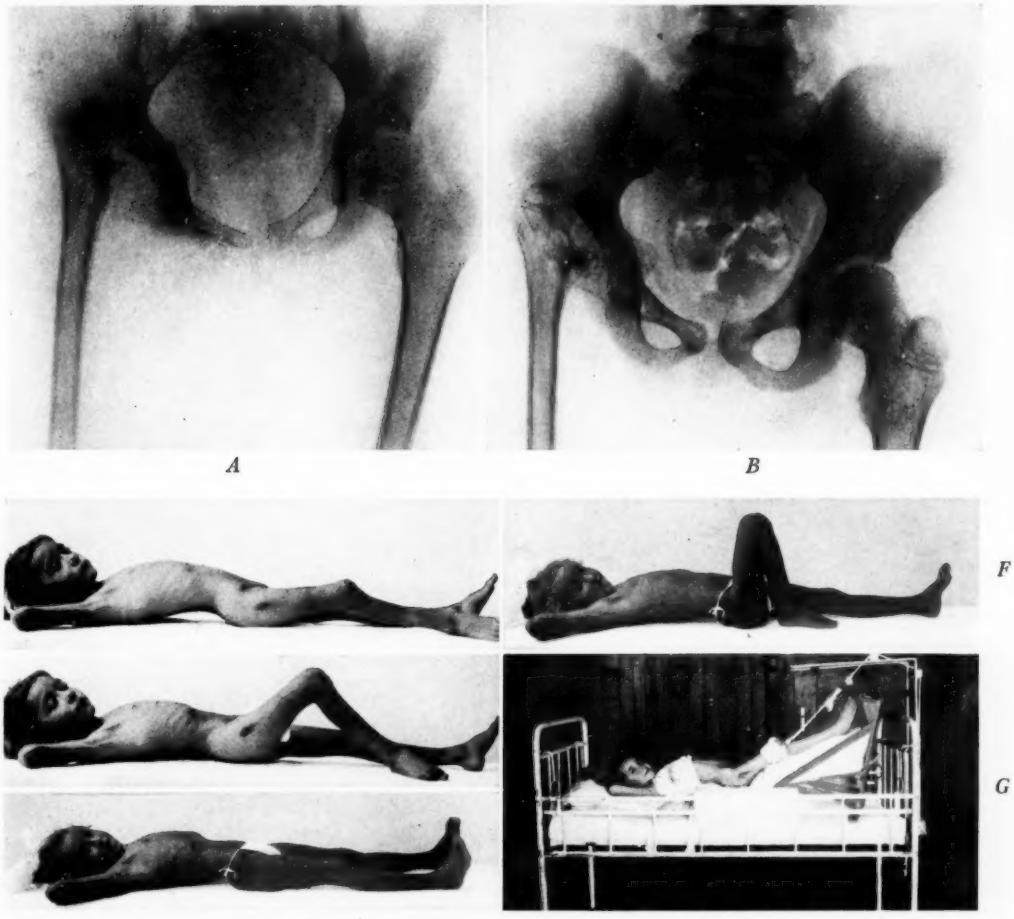

Fig. 11. *A*, Roentgenogram of patient with acute tuberculous coxitis, showing luxation after destruction and loss of head and neck. The whole joint is damaged and shows no clear structure. *B*, Partial correction of the vicious attitude, solid reparation of the floor of the acetabulum. General recalcification. *C*, Photograph of patient showing bad general condition, muscular atrophy. *D*, On arrival. *E*, Patient cured after 15 months. *F*, Showing the return of articular function. *G*, Our apparatus of extension on an inclined plane.

struction by stages: a strong partition of rough structure is first laid down, which then becomes compact and regular: a new articular cavity is formed, firm and delimited, allowing a functional adaptation of the new femoral head to an often unhoped for degree. Once the bony cicatrization is complete clinically and radiologically, the period of training for the vertical position and for exercise begins. Prudent graduation is naturally essential with the ordinary precautions. The legs are bandaged with elastic bandages to prevent abrupt dilatation of the venous network; orthopedic insoles are placed in the shoes to support the plantar arch, and avoid flatfoot, etc. As regards the celluloid apparatus which we formerly used to support the hip joint, experience has gradually led us to abandon it in most cases. Cases of hip joint tuberculosis cured by heliotherapy are generally provided with such a solid muscle scaffolding that a supporting apparatus is quite superfluous. The patient should not use crutches when beginning to walk, as they have a

Fig. 12. *A*, Roentgenogram of patient with tuberculous coxitis showing disparity of contours of internal structure of head of the femur. The acetabulum is filled with a fungous mass. *B*, Cure; reappearance of the circumference of the head with a firm structure. Satisfactory sclerosis of the acetabulum border. *C*, Photograph of patient cured after 1½ years. *D*, Same patient showing the return of articular function.

tendency to deform the spine; ordinary long sticks held at the shoulder level so as to expand the chest are used in our clinics.

The results obtained by heliotherapy are, I believe, conclusive, and a careful study of the appended roentgenograms will enable any one to come to the same conclusion. These results are a proof of our contention that heliotherapy may be considered as the ideal conservative treatment for tuberculous hip disease. The treatment, has in addition a considerable social value. By avoiding mutilating operations and developing a splendid musculature, it retains in most cases the articular function in its integrity, and gives back to the body a symmetrical harmony. To sum up it enables us to give back to society normal beings splendidly fit, capable of working for their living.

NOTE.—Detailed clinical records of cases of hip disease are to be found in the theses of my old assistants: Dr. Vodoz, whose article was entitled "Héliothérapie de la coxalgie et ses résultats (University of Lausanne, 1916); and Dr. Miéville, whose article was entitled "Etude de la fonction articulaire des arthrites tuberculeuses traitées par l'Héliothérapie." For more precise details concerning heliotherapy in general, my book on "Heliotherapy," published by Oxford, second edition, may be of value.

FROM THE DIVISION OF SURGERY, MAYO CLINIC

TECHNIQUE OF REMOVAL OF CYSTS AND SINUSES OF THE THYROGLOSSAL DUCT

By WALTER E. SISTRUNK, M.D., F.A.C.S., Rochester, Minnesota

TO operate satisfactorily for the removal of cysts or sinus tracts of the thyroglossal duct, a surgeon should thoroughly understand the mode of development of such cysts and possess accurate knowledge of the anatomy of the base of the tongue and surrounding structures.

Early in fetal life, before the hyoid bone develops, the thyroid gland appears at the base of the tongue and descends in the median line of the neck. In normal individuals, the epithelium-lined tract produced by the descent obliterates; if obliteration fails to occur completely, the secretion produced by the epithelial tract probably empties through the foramen cæcum into the mouth. Should this opening into the mouth lose its patency, through inflammatory or obliterative changes, the secretion works downward along the tract through which the thyroid gland has descended and produces a cystic tumor in the median line of the neck, usually at a point about midway between the hyoid bone and the top of the thyroid cartilage. The cysts, after passing downward below the hyoid bone, become superficial and lie beneath the raphe, joining the sternohyoid muscles and the thyroid cartilage; they occasionally descend as low as the sternal notch but are always found lying in the median line or very close to it, thus differing from branchial cysts or sinus tracts which are always lateral to the median line.

Should a sinus tract be present, it should be injected with a weak solution of methylene blue in order to outline its course definitely. Under general anæsthesia,[1] with the patient in the usual position for performing thyroidectomy, a transverse incision 5 or 6 centimeters long is made over the cyst through the skin, subcutaneous tissues, and platysma muscle[2] (Figs. 1 and 2). The cyst or sinus tract will be found lying under the raphe joining the sternohyoid muscles. This raphe is cut longitudinally and the cyst dissected free from its attachments up to the hyoid bone. The tract usually passes underneath this bone

[1]Local anæsthesia may be used if desired.

[2]The incision is made so that a sinus opening, if present, may be removed.

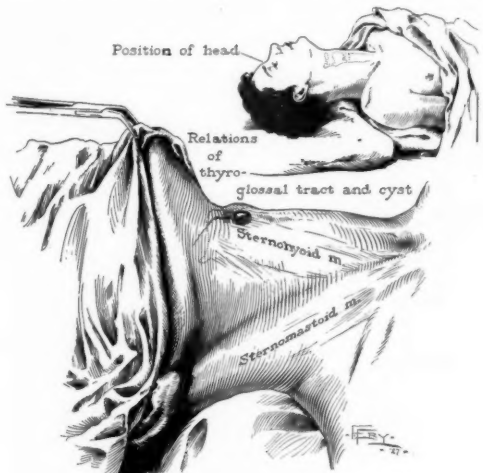

Fig. 1. Cyst and tract in relation to muscles and hyoid bone. Insert shows position of head for thyroglossal duct operation.

Fig. 2. Position of incision.

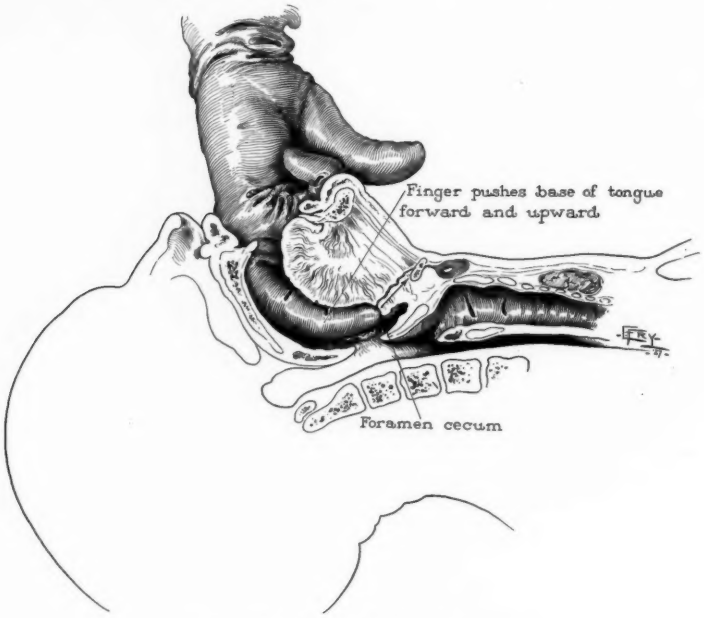

Fig. 4. Finger in mouth elevating tract.

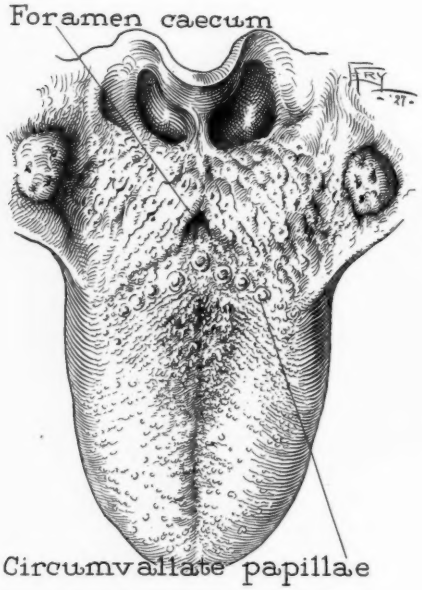

Fig. 3. Position of foramen cæcum.

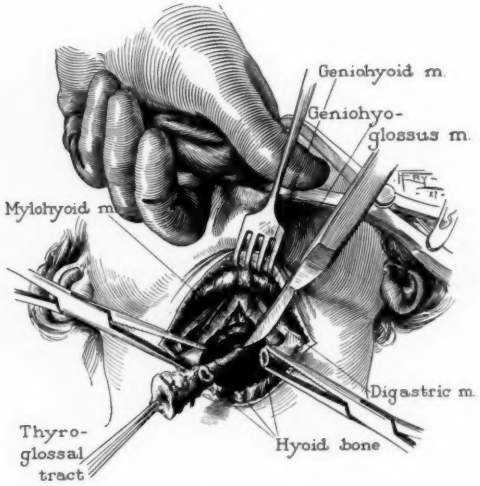

Fig. 5. Cutting off end of tract.

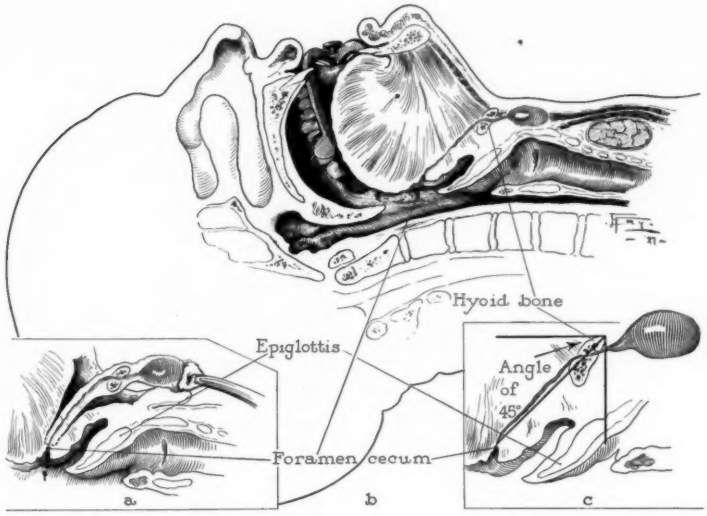

Fig. 6. *a*. Dissection of tract down to mucous membrane. *b*, Position of tract. *c*. Angle of tract.

but may pass superficial to it or through it. In order to remove the duct completely at this point, a small segment, 2 or 3 millimeters in diameter is removed from the center of the hyoid bone. The mouth is then held open with a gag and the tongue pulled forward with a suture or small stomach forceps. The index finger of the left hand is introduced into the mouth and the foramen cæcum located by palpation (or inspection). This may be done by following the two rows of circumvallate papillæ, one of which lies on each side of the tongue, backward to the point where they join in the median line. The foramen cæcum lies just posterior to this point (Fig. 3). This is pushed forward and upward with the finger in order to shorten the distance between it and the hyoid bone (Fig. 4). Then, without an attempt to isolate the duct, the duct and the tissues surrounding it for a distance of about 3 millimeters on all sides, are cored out through the muscles of the tongue to the mucous membrane at the foramen cæcum, where they are cut off without opening the mucous membrane of the mouth (Fig. 5). In doing this it is necessary to bear in mind the direction of the thyroglossal duct. With the patient in the position suggested, this corresponds to a line drawn at an angle of 45 degrees backward and downward toward the foramen cæcum through the intersection of lines drawn horizontally and perpendicularly to the center of the hyoid bone; that is, it corresponds to a line drawn from the center of the hyoid bone to the foramen cæcum (Fig. 6).

In temporarily disregarding the duct and coring out the tissues through which it passes, lies

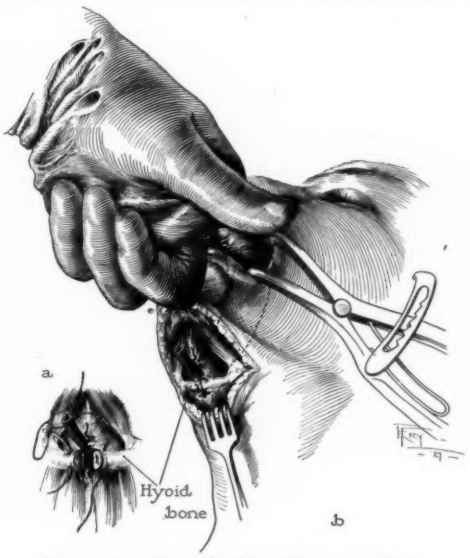

Fig. 7. Suturing ends of hyoid bone together.

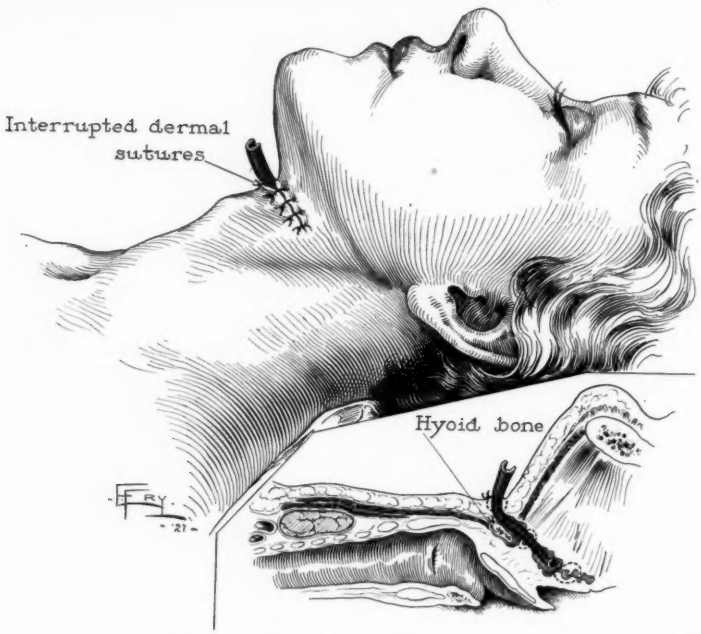

Fig. 8. Wound closed with drainage tube in place. Insert also shows drainage tube.

one of the secrets of cure, as the duct is so small and delicate that it is almost invariably broken, retracts and is lost if efforts are made to dissect it out alone. The finger in the mouth serves as an excellent guide to prevent entrance through the hyo-epiglottic fold into the mouth or into the pharynx.

In dissecting out the duct, a portion of the hyoid bone, portions of the raphe of the mylohyoid muscle, and portions of the geniohyoid and geniohyoglossus muscles are removed.

The opening through the muscles of the tongue is closed with several interrupted catgut sutures passed superficially through the muscle of the tongue (in order to avoid the hypoglossal nerves), and the edges of the hyoid bone are brought into apposition with one or two chromic catgut stitches taken through the periosteum of the bone and tissues adjacent to its cut ends (Fig. 7). A small rubber tube is introduced deeply into the muscles of the tongue, and is allowed to remain for 4 or 5 days. The skin wound is closed with interrupted dermal or horse-hair sutures (Fig. 8).

No harm has resulted in a large group of cases by removal of a small segment of the hyoid bone, and following such an operation, properly performed, practically 100 per cent of the patients are cured.

REPAIR OF INTERNAL RING IN OBLIQUE INGUINAL HERNIA

By F. GREGORY CONNELL, M.D., Oshkosh, Wis.

THE internal or abdominal inguinal ring is the landmark that distinguishes the two types of inguinal hernia. In the indirect, or oblique, the sac passes through the internal ring; in the direct, which is practically a ventral hernia in the inguinal region, the sac passes not through, but below, the internal ring (Fig. 1).

With large indirect or oblique inguinal herniæ, the internal ring may be dilated to such a degree that its lower margin approaches the pubic arch. Under these circumstances there is still an anatomical distinction, but little practical difference between oblique and direct herniæ and a plastic repair similar to that for direct hernia is indicated.

The internal ring may be likened to the "keystone of the arch" in nature's architecture of the inguinal canal. Under normal circumstances this structure helps to prevent the protrusion of viscera through the inguinal canal. It is situated at the entrance to the inguinal canal and one may reasonably suppose that if this structure is normal in its relationships, contents, size, and position, indirect hernia would rarely develop. The size, position, and relations of this internal ring determine the length, obliquity, and character of the walls of the inguinal canal, all of which are important in nature's method of preventing the development of oblique hernia.

If small the internal ring is high, which means the canal is long and oblique, its lower border and the posterior wall of the canal are strong, firm, tense, composed of transversalis fascia, reinforced by the ligamentum interfoveolare of Hesselbach, and the anterior wall of the canal is composed of red internal oblique muscle and external oblique aponeurosis. On the other hand, if the ring is large, it is low and wide, which means that the canal is short and straight, its lower border and the posterior wall of the canal are weak, relaxed, and often are absent, and the anterior wall is composed of only the external oblique aponeurosis.

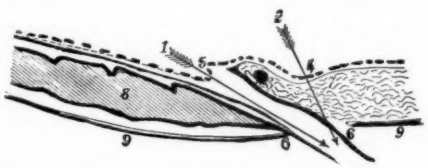

Fig. 1. Showing an oblique and a direct hernia. *1*, Oblique hernia; *2*, direct hernia; *3*, epigastric artery; *4*, internal inguinal fossa; *5*, external inguinal fossa; *6*, external inguinal ring; *7*, intra-abdominal fascia; *8*, internal oblique muscle and transversalis; *9*, aponeurosis of the external oblique. (From von Bergmann, 4.)

These relationships are shown in parallel columns as follows:

INTERNAL OR ABDOMINAL INGUINAL RING

	Normal	Abnormal (hernia)
Abdominal aspect	Smooth, parietal peritoneum	Bulging parietal peritoneum, hernial sac
	Normal	Abnormal (hernia)
Cutaneous aspect	Internal oblique muscle	External oblique aponeurosis (Internal oblique above internal ring and sac)
Superior margin	Transversalis fascia	Same
Inferior margin	Transversalis fascia reinforced by fold of the ligamentum interfoveolare	Same *but* inferior margin may be depressed to pubic bone, depending upon contents of sac
Contents	Cord only, or cord and preformed sac	Cord, sac and contents of sac
Size and position	Small and high	Dilated and inferior margin lower

As the abnormal internal ring allows the protrusion of the sac or the filling of a preformed sac, and the sudden, or gradual, development of a hernia, the normality or abnormality of the internal abdominal ring is followed by normality or abnormality of the inguinal canal.

The *normal inguinal canal* is long, oblique, narrow and contains no sac, the internal ring is high, small; it snugly surrounds the cord and is covered externally by the internal oblique muscle (active muscular check at entrance of canal) and the external ring is low, small, and triangular.

The *hernial inguinal canal* is short, straight, wide, and contains the sac which often extends to the scrotum, the internal ring is lower, dilated, and is not covered externally by internal oblique muscle and the external ring is dilated upward and rounded.

These relationships are shown in parallel columns as follows:

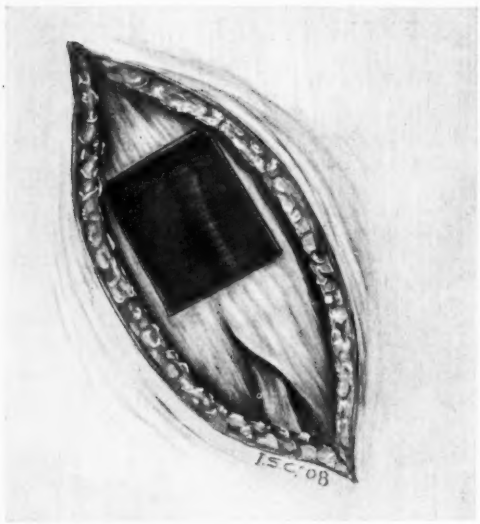

Fig. 2. Normal internal ring.

Fig. 3. Abnormal internal ring; oblique inguinal hernia.

Structure	Normal	Abnormal (hernia)	
		Oblique	Direct
Parietal peritoneum	Smooth, no sac	Sac above internal epigastric artery	Sac below internal epigastric artery
Transversalis fascia	Strong and tense	Strong and tense	Weak, relaxed
Internal inguinal ring	High, small, snugly surrounding the cord	Dilated downward, cord at lower margin transmits sac which is above the cord	Not unduly dilated, cord above and does not accompany sac which is below
Internal oblique muscle	Is anterior to internal ring and covers upper part of cord	Is above internal ring and does not cover the sac and cord	Is usually above internal ring and does not cover sac and cord
External oblique aponeurosis	Covers internal oblique muscle and lower cord	Covers internal ring sac and cord	Covers internal ring, sac and cord
External inguinal ring	Small triangular, transmits cord	Dilated upward and rounded, transmits cord and often sac	Dilated upward and rounded, transmits cord and more rarely sac

Direct hernia will not be considered at this time.

TREATMENT

Given a man with oblique inguinal hernia on one side and normal inguinal relationships on the other, as outlined above, what could be more rational in an attempt at repair of the hernia than to replace in the normal relationships the various structures on the hernia side.

The essentials for the repair of oblique inguinal hernia seem to be:

1. The removal of the entire sac.
2. Reconstruction of the inguinal canal, along anatomical lines based upon knowledge of the normal and pathological anatomy, and physiology which must, of necessity, vary with the type of hernia.
3. Primary wound healing.

The first and third seem practically easy to attain; but the second is not so simple. Much consideration has been given to the walls of the canal and the external ring, but the importance of the *internal* ring seems to have been given little serious attention. To be sure, a new abnormal internal ring is constructed in the Bassini operation, its various modifications, and in other plastic operative cures for inguinal hernia, but the importance of the *normal* internal ring, its relations, and the advisability of reconstructing, or imitating, the normal characteristics of this opening has been scarcely emphasized.

The method of Bassini has become almost a standardized procedure in repair of inguinal hernia; but its result is not anatomical in that the red internal oblique muscle is placed around and below the internal ring instead of covering it superficially, as it does under normal conditions.

This Bassini repair has been much modified by: E. Wyllys Andrews, Ferguson, Halsted, Woelfler, Gerard, Fowler, and others, and more recently by Bates, Harrison, Kerby, Slatterly, Downes, Schley, Stetton, Lyle, Edmund Andrews, Pitzman Seelig, and others.

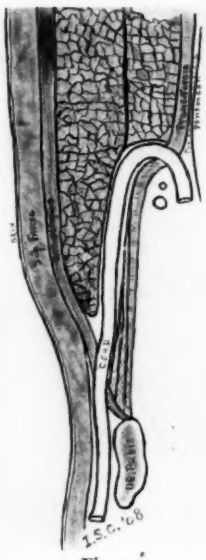

Fig. 4.

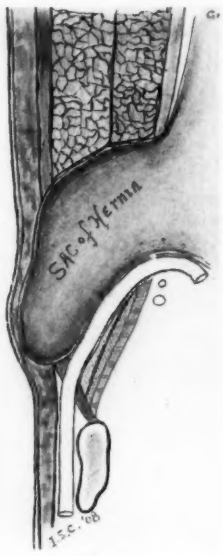

Fig. 5.

Fig. 4. Normal inguinal canal.
Fig. 5. Abnormal inguinal canal; oblique inguinal hernia.

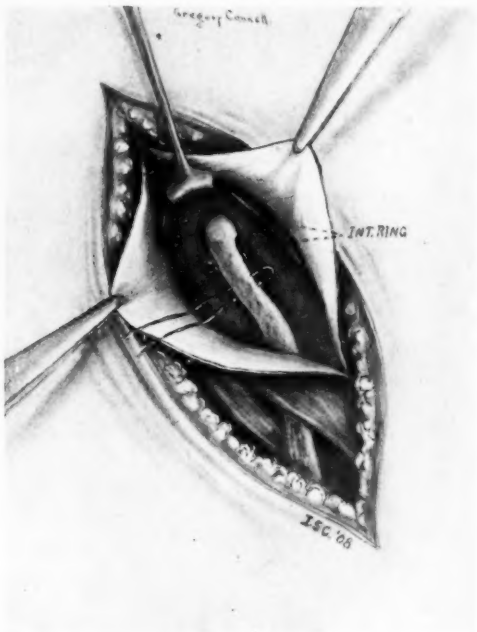

Fig. 6. Repair of internal ring. (From Gregory Connell, 1908.)

Seelig, in 1923, caused considerable controversy by claiming that fascia and muscle would not unite, but Koontz, in 1926, was unable to confirm Seelig's findings. In 1927 Seelig in an article entitled, "Fundamental Principles Underlying the Operative Cure of Inguinal Hernia," finds that fascia will unite with epimysium, perimysium, and endomysium, (the connective tissue covering and between the muscle); and that traumatized muscle because of the exposure of the fibrous tissue trabeculæ, will unite satisfactorily with tendon and aponeurosis.

After the *proper* reconstruction of the internal ring, suture of the internal oblique muscle to Poupart's ligament is rarely indicated, because the muscle will, without suture, cover the ring.

The normal relationship may be re-established by elevation of the ring to a position *behind* the muscle, or depression of muscle in *front* of the ring.

The former is much more satisfactory, but if, in larger hernia, simple elevation of the ring is not sufficient, the muscle, after traumatizing, may be sutured to the outer half of Poupart's ligament with reason to anticipate union.

In the direct, or the large indirect, hernia with relaxed abdominal walls and obliterated or absent conjoined tendons and transversalis fascia, in which satisfactory sutures require so much tension as to defeat their purpose, a plastic operation, preferably with transplantation of living tissue, will be called for; but such plastic operations do not change the underlying *principles* of the attempt made to correct the abnormal inguinal anatomy.

Koontz finds that heterogenous fascia may be used satisfactorily and such fascia is promised for the general market.

The transplantation of free flaps of fascia lata (as advocated by Kirschner, 1909) has been successful in repair of hernial defects, but has now been largely superseded by the modification of Gallie and Le Mesurier in which the fascia transplant is cut in narrow strips and the defect repaired by a darning or interweaving process. This gives much more marginal contact and therefore more likelihood of survival. Such transplantation of tissue is called for in large defects and often after previous attempts at cure.

The imbrication of the external oblique aponeurosis in the method of E. Wyllys Andrews is, in effect, a fascia transplant, as is Mac Arthur's

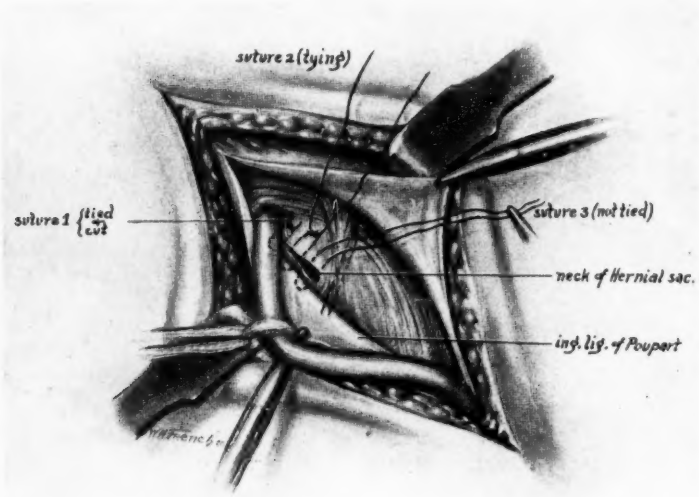

Fig. 7. Repair of internal ring as done by Marsh Pitzman, (12).

utilization of a strip of this same aponeurosis for suture material.

I have utilized the tissue of old, large, thick sac walls themselves as a living suture material. It is only in large herniæ that such material is available and likewise only in these cases that there is a call for such utilization.

Realizing the importance of the natural or normal obliquity of the canal and its valve-like action in preventing hernia, and being impressed with the value of the normal inlet to the canal and of its protection by red internal oblique muscle, as early as 1908 I discussed this subject,[1] called attention to the shortcomings of the non-anatomic Bassini and Ferguson methods, and presented a technique which repaired the internal ring in such a way as to make the canal, the relations of its inlet, its walls, and its outlet, the same as they are in the absence of hernia, in effect an anatomical reconstruction of the inguinal canal.

In the literature since then I have found the following authors who have given consideration to the internal ring and its repair: J. M. White,[2] U. C. Bates,[3] R. V. Slattery,[4] H. H. Kirby,[5] Marsh Pitzman,[6] W. S. Schley,[7] L. F. Watson,[8] Edmund Andrews.[9]

[1] Radical operation for the cure of oblique inguinal hernia. Surg., Gynec. and Obst., Oct., 1908, 481-483. The repair of the internal ring in oblique inguinal hernia. J. Am. M. Assn., 1909, lii, 1087-1089.

[2] New York M. J., 1906, lxxxiv, 71-74.

[3] J. Am. M. Ass., 1913, lx, 2032-2033.

In Pitzman's article entitled "A Fundamentally New Technique for Inguinal Herniotomy," the principle, the object and the method are practically the same as those I had presented in 1909, but with which Pitzman was not familiar.

Our aim in treatment should therefore be to imitate nature, remove the sac, and make the canal, long oblique and small with an active muscular check at its entrance.

The steps in such an attempt may be as follows:

1. Skin incision. Expose external ring and external oblique aponeurosis, the superficial epigastric artery usually requires ligation.

2. Divide external oblique aponeurosis parallel to fibers; expose the inguinal canal and contents, cord and sac, preserving the ilio-inguinal nerve.

3. Mobilize the cord, remove fat and veins if necessary.

4. Isolate and open the sac. Examine the contents, replace them, separate adhesions if present, recognize sliding hernia or bladder in wall of sac (rare in indirect hernia). Examine the posterior wall of the inguinal canal, determine the size and position of the internal ring. Search for

[4] Lancet, Lond., 1917, ii, 455.

[5] Arkansas M. Soc., 1918, xv, 99-104.

[6] Ann. Surg., 1921, Nov.

[7] Ann. Surg., 1923, lxxvii, 607.

[8] Hernia, 1924.

[9] Ann. Surg., 1924, Aug.

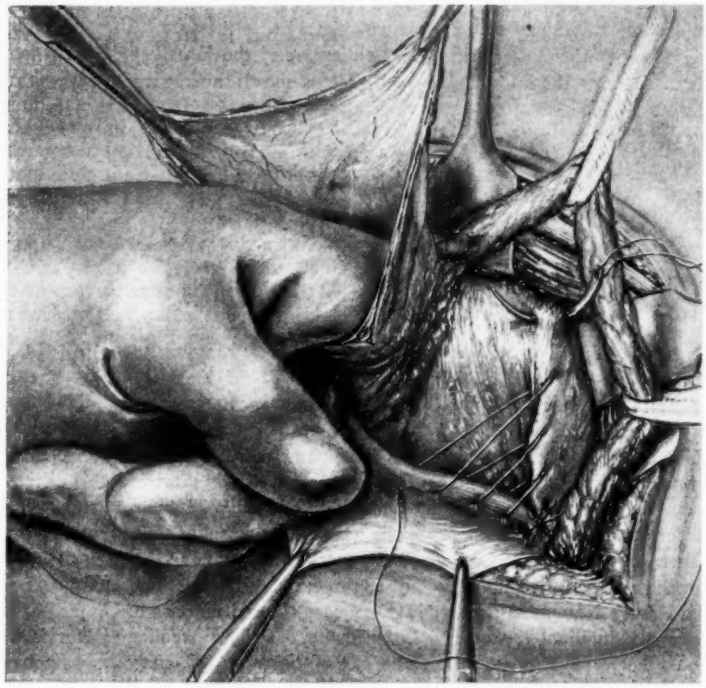

Fig. 8. Repair of internal ring as done by Edmund Andrews, (2).

direct hernia or pantaloon sac with finger in peritoneal cavity.

5. Reconstruct the internal ring and posterior wall of the canal, ring to be minimized and elevated by repair of the transversalis fascia below the cord; which may be carried out in accordance with the method of Gregory Connell, 1909 (Fig. 6); or that of Marsh Pitzman, 1921 (Fig. 7); or that of Edmund Andrews, 1924 (Fig. 8); or that of Major Seelig, 1927 (Fig. 9). If the transversalis fascia, or the posterior wall of the inguinal canal is markedly attenuated, some type of plastic operation will be indicated such as the method of Parks (utilization of thick sac wall as suture material), of Wyllys Andrews (imbrication of external oblique aponeurosis) of Mac Arthur (the use of strips of external oblique aponeurosis as suture material) or of Gallie and Le Mesurier (darning defect with strips of free fascia transplant).

6. Remove sac high up, leaving no redundant parietal peritoneum to pouch outward as a potential sac. Close neck by suture, not a simple circular ligature. Suture of internal oblique muscle to Poupart's ligament is rarely necessary as the internal ring is elevated and usually placed behind the internal oblique muscle.

7. Reconstruct the anterior wall of the canal by suture of the divided external oblique aponeurosis, by imbrication or not, according to the extent of relaxation.

8. Reconstruct the external (subcutaneous) ring from above downward, in this way increasing the obliquity and length of the canal.

9. Close of fascia and skin.

Because of a multitude of variable factors, statistics are many times misleading and are notoriously unreliable; but Pitzman has well said "If the theory of this operation is better, *ipso facto*, the practical result will be better." The result in the individual case may depend upon circumstances other than the method of operative repair, such as sex, occupation, age, physical condition, the size and contents of the sac, the accurate differentiation between direct and indirect types; upon technical errors or faults such as failure to remove all of the sac or to recognize a double or pantaloon sac, or to remove dilated

Fig. 9. Repair of internal ring. (Major Seelig, Arch. Surg., 1923.)

veins or fat; upon injury to nerve, placing stitches under too great tension; or upon postoperative complications or accidents. But the most important cause of recurrence is probably the failure to establish the correct relationship between the type of hernia and the character of the operative technique in the individual case, e.g. utilizing one method as a routine in all cases of inguinal hernia.

Published statistics show a great variety in the percentage of recurrences after attempt at repair, from less than 1 per cent to 10 per cent for indirect and from 14 per cent to 25 per cent for direct.

Personal cases in the service of Dr. C. J. Combs and myself show, with transplantation of the cord, i.e. suture of internal oblique muscle under cord, 137 cases traced with 8 recurrences 5.8 per cent; without transplantation of the cord, i.e. in which the internal oblique muscle is not sutured under the cord, 162 cases traced with 4 recurrences 2.46 per cent.

As in all statistics, these figures are likewise misleading in that the early, simple, small herniæ are in the more favorable group, while the late, complicated and larger cases are in the less satisfactory group.

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LEAD TREATMENT OF CANCER

By H. J. ULLMANN, M.D., Santa Barbara, California
Director of the Department of Cancer Research, Santa Barbara Cottage Hospital

WE have presented evidence in previous publications for the use of colloidal lead orthophosphate rather than the metallic colloid in the treatment of cancer. We have shown, both from animal experimentation and from clinical experience, that the phosphate is much less toxic to the organism as a whole, than the colloidal metal or its other salts (1, 2, 3). We believe that the solutions, as generally employed, are so toxic that their use is open to question and their keeping qualities are such that it would be difficult, if not impossible, to bring them into general use. Solutions of lead orthophosphate keep indefinitely at room temperature and apparently do not alter their toxicity with age.

As I have been using lead preparations in the treatment of cancer for less than two years, it is too early for me to evaluate the method, but I have seen sufficient effect on tumors, especially those of the breast, to feel considerable encouragement. I do not believe it should, at present, take the place of the time tried methods of surgery and radiation, but should be reserved for those unfortunates who are beyond the reach of either. It is necessary, in order to obtain the maximum benefit, to combine the roentgen ray or radium with the lead injections and, therefore, absolutely essential that the user be, not only a good clinician, but a radiologist as well, or be in close co-operation with a competent radiologist. He must be familiar with the effects of lead and of radiation, not only on the tumor, but on the body as a whole and must be prepared to combat lead as well as roentgen intoxication. The majority of patients tolerate lead very well, but there are some who are easily poisoned and present the most serious problem of the many involved in this method of treatment. For the present, I consider it advisable to hospitalize all patients undergoing lead treatment. It is much easier in a hospital, to keep them under close observation and to perform the necessary clinical laboratory work. It is much more difficult to control the diet at the home than at the hospital and the question of diet becomes more difficult as the treatment progresses. Loss of appetite is practically constant toward the end of treatment, especially when radiation sickness is superimposed on lead intoxication.

From our experience, I believe that the only direct contra-indications to the use of the lead phosphate to be a severe anæmia and perhaps lung involvement not secondary to breast carcinomata. Several deaths have occurred in our clinic from liquefaction of lung nodules following the injection of both the metallic colloid and the colloidal phosphate. These were metastatic from tumors of the liver, colon, and cervical glands. On the other hand, lung tumors secondary to breast carcinomata have regressed without untoward symptoms. I have injected the phosphate in several instances where the kidney function, as shown by the dye test, was almost zero and in one instance was actually zero. No demonstrable kidney injury has been found in any instance, so far, following the use of the phosphate.

Our technique at present consists in hospitalizing the patient and making a careful examination, both physical and laboratory. In addition to the routine examination of the urine and blood, the kidney function is estimated by the dye test, and blood smears are searched for stippled cells, which may be found in some cases of advanced carcinoma before lead is used. The solution of colloidal lead phosphate is then injected intravenously, the amount varying with the weight of the patient and the size of the tumor. I have not as yet given more than 0.7 milligrams of lead element per pound of patient, net weight. The average dose has been 80 milligrams, although we believe larger doses may be safe and perhaps more efficient. Our experience with the metallic colloid has left a great impression and we have been slow, perhaps too much so, in increasing our dose. Doctors Withers and Ranson of Denver, who are using our preparation, have given as high as 120 milligrams at each injection and have had some marked regressions and disappearances of tumors. The question of dosage is still under investigation and I believe that we will be obliged to vary it according to the type as well as size of tumor and weight of patient.

Blood counts and the search of smears for stippled cells are made at intervals and if, in our opinion, the fall in hæmoglobin has not been too great or there are not more than an average of one stippled cell per high power field, the dose is repeated in one week. These weekly doses are repeated until from 300 to 500 milligrams, usually

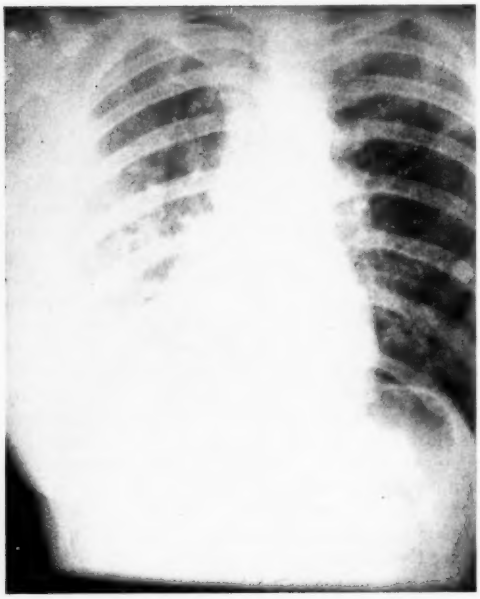

Fig. 1. Case 1. Lung fields, December 20, 1926, before injection of lead.

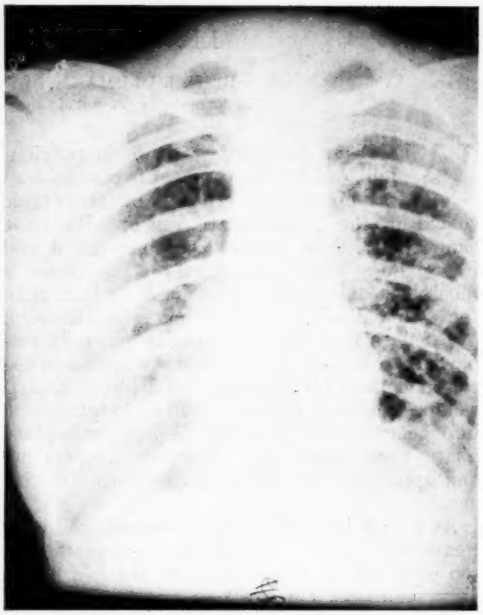

Fig. 2. Case 1. Lung fields, March 30, 1926, showing increase of markings following use of lead.

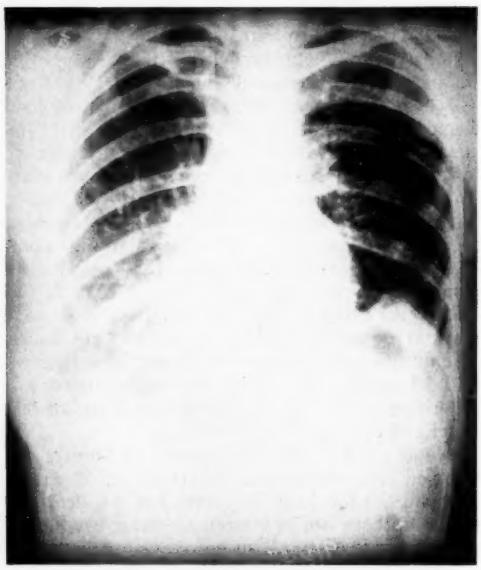

Fig. 3. Case 1. Lung fields, September 21, 1927.

400, have been given. Radiation, either radium, the roentgen ray, or both, is begun, when from 200 to 300 milligrams have been injected, but great care is taken to prevent radiation sickness. I follow the general plan I outlined several years ago, to prevent this (4) and in addition do not hesitate to fractionate the dose to any degree necessary. Blood transfusions are done whenever indicated and it has been found that the general condition of the patient is a better guide to the necessity of such a procedure than the degree of anæmia. It must be understood that these procedures are never rigidly adhered to, but are modified as necessary in any individual case. No one should attempt the use of lead without first reading all the articles published by Bell and his associates and a thorough study of the entire book—"Lead Poisoning," by Aub, Fairhall, Minot, and Reznikof. The patient is given a 4 to 6 weeks' rest and the treatment is repeated until a total amount of from 500 to 600 milligrams have been given. Two grams of calcium lactate and 1 quart of milk are given each 24 hours, if necessary to combat symptoms of lead poisoning.

From our observations during the last 18 months I believe that the use of lead in the treat-

Fig. 4. Case 2. Photograph, June 12, 1927, one month after treatment was begun.

ment of cancer holds sufficient promise to warrant thorough investigation, but the method has not been developed far enough to warrant its general use. Under the best conditions there are many disappointments and this is especially true now, when the majority of patients, on whom it is tried, have reached a stage in their disease when nothing, even if it could produce a complete cure of the cancer, as such, could offer hope of recovery, so far as the patient himself is concerned.

Two cases are presented to illustrate the effect of lead on cancer of the breast. The first was reported at the Washington meeting of the American Medical Association (3) and is reported again because of the still further improvement of the lung metastases.

This patient was a woman, 44 years old, who had had a radical resection of the left breast, 3½ years ago, for carcinoma and, later, subcutaneous nodules were removed on 2 occasions. Roentgenotherapy had also been used. On December 20, 1926, there was a 7 by 14 centimeter tumor in the right breast, covered by markedly erythematous skin. Above this was an axillary node about 2.5 centimeters in diameter. Both supraclavicular and cervical regions contained multiple nodules. The supraclavicular space on the left contained a hard tender mass, approximately 4 centimeters across. There were multiple subcutaneous nodules scattered over both the anterior and posterior thorax and cutaneous nodules in the region of the operative scar, some of which were about to ulcerate. There was separation of both retinæ and a slight painful bulging of the right eyeball.

Fig. 5. Case 2. September 14, 1927.

There was a slight productive cough and dyspnœa. Both lung fields were mottled (Fig. 1).

Colloidal lead phosphate was given intravenously. Following the second injection, the cough disappeared, but pain was felt in all the tumors. A primary swelling of the visible tumors occurred, followed by regression. A radium pack applied over the right temporal region produced immediate relief of the pain and swelling. Vision was completely lost at about the mid-period of treatment. Radium packs were applied to the right breast and axilla and left supraclavicular region, followed by immediate regression of the tumor. There had, however, been a reduction in the size of the right breast and a complete disappearance of the erythema before radium was used. The subcutaneous nodules regressed steadily, although unradiated, and some in the region of the scar disappeared entirely.

The change in the lung fields is particularly interesting (Fig. 2). There was a marked increase in the density and size of the tumor shadows, although the patient was clinically better. This was interpreted as due to an infiltration and swelling of the tumor nodules—a lead reaction. Small doses of roentgen rays were then given over the thorax, without producing the slightest general reaction. By May 5 the lungs had shown marked improvement and there was regression or disappearance of the visible tumors. The total amount of lead element used was 602 milligrams between December 22, 1926, and August 24, 1927. No further treatment is contemplated unless there is recurrence. The appearance of the lung fields on September 21 was such (Fig. 3) that, taken in conjunction with the disappearance of the palpable nodules, one is inclined to report disappearance of the metastases as such. The cutaneous, subcutaneous, and cervical nodules have disappeared. There is a flat, symptomless induration found on palpation in the left supraclavicular space. The right axillary

nodule is gone and a slight, diffuse, rubbery induration is all that is left of the mammary tumor. Vision in the right eye is lost, but pictures can be recognized with the left and she is able to write letters and read fairly large writing and to go about town without assistance. She is gaining weight and feels well. There is no evidence of chronic plumbism.

The second patient gave her age as 61 years, but I have information which leads me to believe that she is over 80 and her appearance is that of the greater age. The description of the tumor is that written by my assistant when she entered the hospital: right cervical and supraclavicular adenopathy; large, foul smelling ulceration of upper third of right breast, 5 centimeters in diameter; the center is necrotic with rolled out, indurated edges. The entire breast is very hard and the skin is tense, brawny, and dark red. There are large hard glands in the right axilla. The left breast is firm and the medial half is a hard mass. Both breasts are fixed to the chest wall. There are large, firm glands in the left axilla. The skin of the lower thorax is thick, indurated and dark red. The right arm is swollen, tense, and cyanotic. The hand cannot be closed.

Because of her age and general physical condition, lead was given in small (40 milligram) doses. Immediate regression of all the tumors was observed. Due to carelessness, no photograph was made for several weeks and when taken, there was a reduction of nearly a third in the size of both breasts (Fig. 4). Because of her age and the size of the tumor, we have treated cautiously. She has, on several occasions, developed a toxic psychosis when the tumors were regressing rapidly, necessitating postponing further treatment until recovery. These never lasted more than a few days. Since May 12, when treatment was started, to September 22, she has received a total of 450 milligrams of lead element in the form of the phosphate, and blood transfusions have been given on 3 occasions. There has been marked shrinkage of the tumors (Fig. 5) and she can now lift her arm to shake hands and can close the hand. There is no odor, bleeding, or ulceration, as the necrotic area has healed. Because of the extent of the malignancy and the age of the patient, I have little hope of ultimate recovery, but the relief of such a condition, even if only palliative, I believe worthy of report, to illustrate the effect of lead on breast cancer. It is hoped that we will be able to confirm our present optimism for the lead treatment of cancer in our subsequent reports.

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INTRA-ABDOMINAL TUBERCULOSIS

By LEO DRETZKA, M.D., F.A.C.S., Detroit, Michigan

TUBERCULOSIS has almost as many angles of interest as syphilis. It has its sociological, hygienic, genetic, occupational, and psychological aspects in addition to its medical and surgical phases and we can not approach it from any of these viewpoints without considering the others.

The ultimate conquest of tuberculosis, and statistics give us sound reason to believe that it will eventually become as rare in civilized countries as cholera, will be the triumph of the hygienist and epidemiologist. The surgeon's aid in the treatment of individual cases must be regarded as only a temporary recourse, an emergency measure applied in lieu of something better. The physician should call upon the surgeon for co-operation only when the tuberculous infection is not to be reached by any other method; and if surgical interference is to justify itself the postoperative treatment must be recognized as by far the most onerous aspect of the case when the tuberculosis has progressed into certain tissues.

The results obtained in tuberculous infections with direct sunlight and proper hygienic conditions have been most encouraging in recent years. If all patients could be given this treatment for an unlimited period of time, surgical treatment should really be deferred in the majority of cases of intra-abdominal tuberculosis. Unfortunately, our patients in most parts of the United States cannot be given ideal climatic conditions.

During 1924 and 1925, I studied 72 cases of surgical tuberculosis of the various abdominal organs. Of this group, 16 were cases of definitely primary abdominal infections, in so far as could be determined by examination. In other words, the respiratory organs were normal, as were all parts of the body, excepting the affected part, and the end-result, after surgical intervention, indicated a complete recovery.

TUBERCULOSIS OF THE PERITONEUM

Tuberculosis of the peritoneum is most common in children and young adults. In the early

Fig. 1. Tuberculosis of the cæcum. Operative case with removal of terminal ileum, cæcum, and ascending colon. Massive tuberculosis of cæcum with obstruction and marked tuberculous enlargement of cæcal lymph glands.

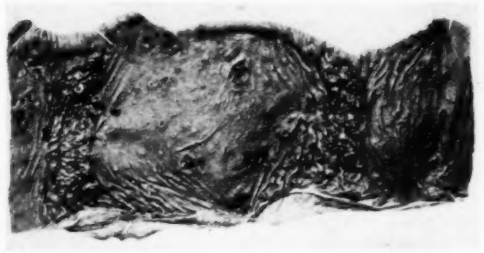


Fig. 2. Tuberculosis of the ileum with tuberculous ulcerative enteritis. Young and old tuberculous processes in the ileum, some with beginning ulceration and others with advanced ulcerative change. Note the typical transverse disposition of the advanced ulceration. Autopsy showed a bilateral caseous ulcerative pulmonary tuberculosis with extensive tuberculous enteritis and ulceration; also localized tuberculous peritonitis over the ileum.

stages, the disease has no characteristic symptoms and is, therefore, frequently overlooked until effusion takes place. The initial symptoms are abdominal discomfort, loss of appetite, and frequent attacks of colic. The presence of these symptoms, together with anæmia, loss of weight, and the typically rounded abdomen should arouse the examiner's suspicion in the direction of tuberculous peritonitis. Various types are found, depending apparently on the virulence of the infection and the mode of entrance.

The organisms may enter through the blood stream, the intestinal walls, through any caseous focus which may extend to the peritoneum or, most frequently of all, through the fallopian tubes. In most instances, abdominal tuberculosis is secondary to an infection elsewhere, but this is often difficult to prove.

Macroscopically, we find minute miliary tubercles on the peritoneal surfaces and in the omentum without any accumulation of fluid or exudation of fibrin. In other cases a quantity of clear or turbid fluid is present in the cavity. Usually the amount of fluid is small, but it may be found in quantities large enough to distend the abdominal cavity.

In this moist form, the patient loses weight and strength rapidly. The abdomen has a characteristic paleness and the skin is silky. When the abdomen is opened, a thin fluid escapes. Flakes of fibrin may escape with the fluid. The fluid having escaped, the surface of the peritoneum is seen to be studded with fine tubercles. Some of the tubercles may be of considerable size. Masses of caseous mesenteric glands may now be palpable. The omentum may be greatly thickened and infiltrated. In the dry variety there is no effusion, and extensive adhesions may form between the intestinal coils. Frequently a fæcal fistula is present. The surrounding tissue is inflamed and the blood vessels distended.

TUBERCULOSIS OF THE INTESTINES

Tuberculosis is the most frequent cause of inflammatory affections of the bowel. Tuberculous lesions are rarest in the duodenum, becoming more frequent as one nears the ileocæcal valve. As to the mode of entrance, except in the cases of children, in which the tubercle bacilli may reach the bowel through the digestive tract, the bacilli pass

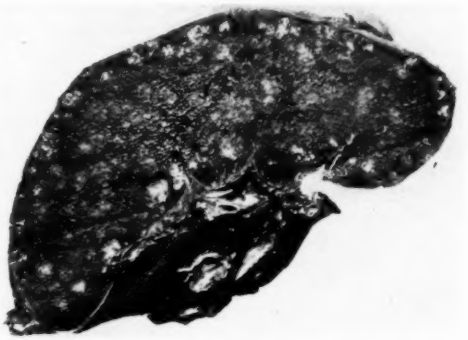


Fig. 3. Tuberculosis of the spleen. The spleen is enlarged, the capsule fibrous and thickened. There are disseminated miliary tubercles throughout the parenchyma, with occasional agglutination between tubercles. Autopsy showed a generalized miliary tuberculosis involving the spleen, liver, omentum, mesentery, small intestines, and lungs. There was also a right psoas abscess with early necrosis of adjacent vertebral bodies.

Fig. 4. Tuberculosis of mesenteric lymph glands. Autopsy showed a generalized productive type of tuberculosis (bovine) involving the mesenteric lymph glands, retroperitoneal lymph glands, prostate, and seminal vesicle (left). The glands were exceptionally large and showed extensive massing. The lungs showed bilateral productive tuberculosis and the left pleural cavity an exudative pleurisy. Large cerebral tuberculomata were also present.

Fig. 5. Tuberculosis of the omentum. The omentum is dotted with small miliary tubercles.

through the stomach and lodge on the intestinal mucosa, either in the lymph nodules or elsewhere. There inflammation is followed by ulceration of the mucosa and submucosa. The girdle ulcer follows. The inflammatory process may extend through the muscular coat and a perforation result, but the inflammatory thickening of the serous coat usually prevents a rupture. Adhesions to surrounding parts are common. The surgical importance of ulcerative tuberculosis in which extensive ulceration has been present lies in the fact that healing is followed by scar contraction. Intestinal obstruction may result, and is treated in the regular manner. The tuberculous condition is unrecognized until symptoms of obstruction present themselves.

During the operative procedure the entire intestinal tract is systematically examined, by beginning with the cæcum and tracing its course, and following the small bowel down from the jejunum. The bowel must be handled with extreme gentleness and care. Shock must be minimized. Rough handling of the bowel may result in an active inflammatory reaction.

The ulcers are irregularly distributed, but are usually in the region of the ileum. (Figs. 1 and 2.)

Acute tuberculous inflammation of the ileocolic glands often simulates appendicitis.

TUBERCULOSIS OF OTHER ORGANS AND GLANDS

Tuberculosis of the stomach wall, or the existence of tuberculous ulcers of the stomach, is comparatively rare, although, with the swallowing of tuberculous sputum, one would expect the direct opposite. The tuberculous ulcers that are found are probably primarily ordinary gastric ulcers infected by the organisms.

Tuberculosis of the gall bladder is extremely rare and simulates gall-bladder disease in general.

Tuberculosis of the liver is not uncommon, but is seldom extensive, and for the most part consists of minute tubercles, scarcely visible. It is always secondary.

It is doubtful if tuberculosis of the spleen is ever primary. Frequently, however, the spleen is involved along with other organs (Fig. 3).

Involvement of the cervical, bronchial, and mesenteric lymph glands is common, occurring most frequently during childhood. The pasteurization of milk during recent years as well as the hygienic inspection of school children has done much toward eliminating this infection. The mes-

enteric glands are infected by the bacilli which pass through the bowel wall (Fig. 4).

Tuberculosis of the uterus most frequently follows a tuberculous infection of the tubes. The disease occurs in the form of nodular or diffuse infiltration which resolves itself into ulceration or necrosis of the mucous membrane and submucosa. The entire organ may be covered by necrotic and caseous deposits.

TUBERCULOSIS OF THE FALLOPIAN TUBES

In the female genital tract, the fallopian tube is the area most frequently infected by the tubercle bacillus. The fallopian tube is usually the primary seat of the disease, and a large majority of cases of general abdominal tuberculosis and tuberculous peritonitis is due to an extension of the infection from this point.

The susceptibility of the fallopian tubes to this form of infection is explained on the ground that the mucosa offers a fertile bed, the result, I suppose, of the circulatory changes occurring at menstruation. This probably accounts for the fact that the infection takes place often between the periods of puberty and the menopause, or, in other words, during the active sexual life.

As a result of improved methods of diagnosis, an increasing number of cases of tuberculosis of the oviduct are being reported as primary.

In my series of cases there are 3 in which the oviduct is the only site of tuberculosis. I think much caution should be exercised in pronouncing the condition primary; only after the most meticulous examination is such a diagnosis warranted.

The pathologists inform us that the mucosa is the first portion of the tube to be attacked, the infection then spreading until all coats are affected. Tubercles are present on the peritoneal surface of the tube in only about 50 per cent of the cases. But the flare of the fimbriated end of the tube glistening and moist is quite characteristic. The tube may be normal in size or greatly enlarged. Caseous material is often seen, and in advanced cases the peritoneal surface is coated with a yellowish gray, cheesy material. Certain types of tuberculous salpingitis resemble chronically infected tubes and cannot be distinguished from pyogenic infections. Leucorrhœa is present in 75 per cent of the cases.

The macroscopic diagnosis of tuberculous salpingitis is entirely misleading. The tubal tuberculous involvement is most frequently discovered by histological examination. The uncertainty of an accurate macroscopic examination accounts for the divergent opinion regarding its frequency.

Statistics, which place the incidence of genital tuberculosis at from 1 to 12 per cent, are unreliable because there is no evidence that a routine histological examination has been made. The University of Pennsylvania has found that in their series of cases 7 per cent of all inflamed fallopian tubes are tuberculous.

During 1923 and 1924, 215 cases of salpingitis were operated on at St. Mary's Hospital. Of this number 8.5 per cent were reported as tuberculous. All operative material at our hospital is subjected to histological examination.

A description of the characteristic symptoms of tuberculous salpingitis is quite impossible. In the earlier stage of the disease recurrent attacks of pain and tenderness, with some degree of menstrual disturbance, may be present. Elevation of temperature is common. When it is remembered that the abdominal ostium is usually open and the tube patent, it is understandable how obscure early symptoms may be. As the disease progresses, adhesions may obstruct the lumen of the tube and the tube may become adherent to the bladder with resultant urinary symptoms. Secondary anæmia is present in the majority of cases with resultant menstrual differences. These symptoms are likewise characteristic of pulmonary tuberculosis. The symptoms resemble any pelvic inflammatory condition in its varied degrees, with the exception that in tuberculous infections the acute symptoms are vaguely marked while the constitutional symptoms are often very pronounced. Sterility is frequent and in my series 90 per cent of the patients were apparently sterile.

The operative mortality in properly selected cases of tuberculosis of the tube is no greater than that of other tubal infections. We must consider, however, that the condition is usually secondary to tuberculosis elsewhere, and this of necessity makes the risk greater and the choice of anæsthetic more important.

Operative treatment. Excision of the diseased parts is the necessary operative procedure. In my opinion, conservative measures rather than radical ones get desired results. In other words, if the tubes alone are involved macroscopically, a pan-hysterectomy is not indicated; but the tubes should in all cases be excised out of the cornu of the uterus. The ovary is rarely attacked by the tuberculous process. A peri-oophoritis may be present, but it is usually an inflammatory extension. If degeneration is not present the ovaries should not be removed. The condition here is similar to that in the male, in which the epididymis is infected frequently and the testicle

rarely. If the infection is unilateral both tubes should be removed, since repeated histological examinations have proved that this is the safer procedure.

The general operative technique of pelvic surgery is followed. If a mixed infection is suspected, the abdomen should be drained. Analyzing the operative results of 200 cases at Johns Hopkins, Greenberg reports that of 104 cases in which drainage was used, fæcal fistulæ followed in 18; while in 96 in which drainage was not used, no fistulæ followed. As it is impossible to eradicate the process entirely by excision, continued minute detailed attention to the general health of the patient is necessary.

The question of whether to drain or not is determined solely by the nature of the infection encountered. If the infection is mixed, drainage is indicated; if it is exclusively tuberculous, no drainage is used.

After the patient leaves the surgeon's care, the real fight begins. It is almost needless to say that the personality and economic status of the patient are all-important factors. A great many victims of tuberculous infection are saved in spite of themselves. During my connection with public clinics, I saw numbers of patients, who, after being treated surgically for tuberculous infections of the abdomen, if left to themselves or to casual medical care, would return to the most unfavorable surroundings and die a little sooner than otherwise. I have seen patients too ignorant and stubborn to go to public sanitariums, compelled by the physician to spend their days exposed to the sun and air perhaps in some squalid courtyard screened against flies, given the proper diet, and kept from premature exertion while incredulous relatives sneered at the fussiness of the doctors, social workers, and visiting nurses. But since tuberculosis is a far more dangerous disease, from a public health viewpoint, than leprosy, the responsibility of the physician in regard to it must never be limited by the personal notions of its victims.

SUMMARY

When tuberculosis involves organs of the abdomen, and the general condition of the patient is sufficiently good, surgical interference is indicated. It is important first to determine whether the patient has the vital reserves which will make the operation beneficial, and then to perform the operation with due respect for the generally weakened physique. I refer to the careful minimizing of shock, the delicate handling of tissues, and the judicial selection of an anæsthetic and its mode of application. The postoperative care, which by no means ends with the primary healing process, is of the utmost importance.

SYNOVECTOMY OF THE KNEE JOINT

By CLARENCE H. HEYMAN, M.D., F.A.C.S., Cleveland, Ohio

IN recent years the operative removal of the synovial membrane to relieve various affections of the knee joint is becoming more and more recognized as a valuable procedure. Although the writer's series of cases is not large, 7 cases of the complete operation, a sufficient length of time has elapsed to form conclusions as to its value. It is believed that synovectomy in the properly selected case is a procedure of great merit, and has been the only method of obtaining relief for those patients operated upon. It is also the writer's belief, inasmuch as a practically normal range of motion has been obtained in all excepting 1 case in which the infectious nature of the disease was not quiescent, that the indications may be broadened to include that class of cases in which there is painful and limited motion following trauma with recurring synovitis of not clearly understood etiology. It is the purpose of this paper to discuss the indications for synovectomy and the rationale of treatment.

By synovectomy we mean the excision of the synovial membrane as the principal seat of the local pathological change. Strictly speaking, the term synovectomy means the complete operation, i. e., the removal of all the synovial membrane which, of course, includes that of the quadriceps pouch, the infrapatellar fat pads, and the semilunar cartilages. However, I do not wish to limit the discussion to the complete operation, as there are certain types of cases in which all of this is not necessary or advisable, and will therefore include in this paper a discussion of those conditions in which only a partial synovectomy is advisable.

The classification of arthritis adopted here, while not satisfactory, is, I believe, the best we have. I shall not attempt to go into the etiology more than is necessary to determine the indications for synovectomy.

Synovectomy is not new. Although it had long been employed in the treatment of tuberculosis, there is only an isolated report here and there of its use in the so-called arthritis cases. Goldthwait (1), in 1900, was probably the first in this country to remove the thickened synovial membrane in several knees with a constant excess of fluid, pain, and grating on movement. Murphy (2), in 1916, reported 2 cases of synovectomy in villous arthritis.

More than a passing interest, however, was not aroused until in 1922 when Swett (5) read his paper at the American Orthopedic Association on "Synovectomy in Chronic Infectious Arthritis." Although it is not the rule, micro-organisms have frequently been found in the stained synovial membrane removed at operation, and obtained in culture from the synovial exudate. The acutely painful, swollen, and tender joint with local heat and elevation of body temperature leave no doubt as to the infectious nature of the process within the joint; but it is the exception rather than the rule that positive cultures are obtained, even though the aspirated fluid is cloudy and the sediment shows a large number of pus cells. New laboratory methods as suggested by Burbank are quite likely to demonstrate the presence of the offending organisms in a far greater number of cases. Swett reasoned, therefore, that these organisms are capable of continuing the activity of the process within the joint as well as causing metastases into other and previously uninvolved joints, and that there is as much logic in their removal as there is in the elimination of the original portal of entry. In other words, the infected synovial membrane is itself a source of infection, and remains so even after all other foci have been removed. He also believes that a prompt restoration of function stimulates local metabolism which Pemberton has found to be fairly constant as a suboxidation process which prolongs the arthritis.

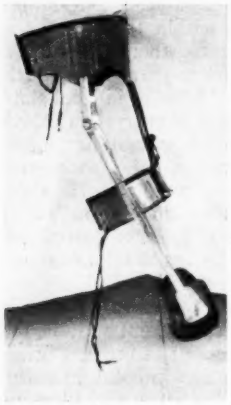
Before we proceed to a discussion of the selection of a diseased joint suitable for synovectomy, it will be necessary to review briefly the anatomy and the changes present in arthritis. It is apparent that the better we understand the reactions of synovial membrane to injury and toxins, the fewer mistakes we shall make in selecting our cases for synovectomy.

The synovial membrane lines the deep surface of the ligamentous structures of the lateral and anterior parts of the joint. It is reflected over the semilunar cartilages, the infrapatellar fat pads, and the crucial ligaments on the anterior and lateral aspects. It does not completely invest the posterior surface of the posterior ligament. In the anterior part of the joint it is prolonged proximally beyond the articular surface of the femur in the form of a pouch under the cover of the quadriceps tendon. The subcrureus muscle is inserted into the wall of this pouch, and its function is important as it prevents pinching and injury to

Fig. 1.

Fig. 2.

Fig. 6.



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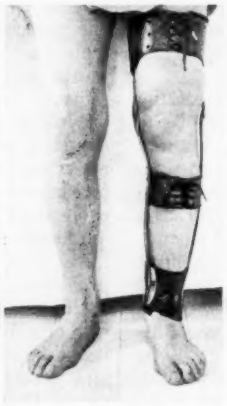

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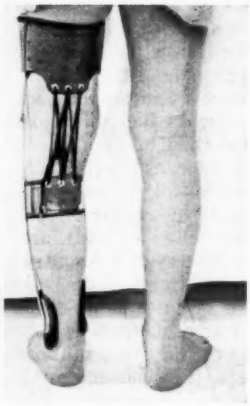

Fig. 5.

Fig. 1. Large bony mass buried within the synovial membrane. Marked hypertrophic arthritis of the patella. Narrowed joint space. This is a mixed type.

Fig. 2. Proliferative bone changes at the margins of the femoral condyles. Otherwise no bone changes. Duration of symptoms—8 years. At arthrodesis, an extensive tuberculosis was found.

Figs. 3, 4, and 5. A satisfactory brace to check extension of the knee. Extension is checked at the desired angle by means of the check bands which are placed at the back of the knee. An accurate fit is necessary above the maleoli. This is obtained by building this part of the brace over a plaster cast of the ankle.

Fig. 6. A case of a very marked villous arthritis. No marked bone changes excepting roughened tibial spines, and a small detached mass of bone.

the synovial membrane on extension of the knee. The synovial membrane also invests the semilunar cartilages, and a pouch-like diverticulum is prolonged posteriorly and distally along the tendon of the popliteus which it partially ensheathes, thus forming a posterior compartment connected with the anterior chamber by narrow passages. Fibers of the gastrocnemius are attached to the posterior capsule, thus again taking up the slack and preventing the pinching of the synovial membrane when the knee is flexed.

The infrapatellar fat pad requires particular mention because of its frequent hypertrophy and consequent internal derangement of the knee.

The pad is extrasynovial but intracapsullar, and is placed under the deep surface of the patellar tendon, and fills up the interval between the patella, femur, and tibia, adapting itself to the various forms which this recess adopts in the different movements of the joint. The synovial membrane separates it from the interior of the joint, and from its surface a band of this membrane extends to the intercondyloid notch where it is attached. This band is termed the ligamentum mucosum, and its lateral prolongations inserted into the capsule are the alar ligaments. These are not ligaments in the ordinary sense of the word, but are merely folds of synovial membrane. Contraction of the subcrureus muscle transmitted through the capsule and alar ligaments is believed to pull the fat pad up out of danger on extension of the knee. Thus, it may be seen that an underdeveloped quadriceps muscle may result repeatedly in injury to the synovial membrane on motion of the joint. We may say in passing that physiotherapy, directed toward increasing the muscle tone and the developing of this muscle, is important in the treatment of knee joint disease and in postoperative cases. Massage directly over the capsule and synovial membrane is contra-indicated as it leads to still further irritation, congestion, swelling, and so forth.

Synovial membrane which has been traumatized becomes congested and swollen, and there may be small extravasations of blood, with exudation of a thin, yellowish fluid containing small flocculi of fibrin. The reactions to injury and infection are very similar, and are manifested clinically as synovitis, or thickening of the synovial membrane and joint capsule. In more severe cases, the exudate becomes more abundantly fibrinous, and the synovial membrane is thickened, swollen, thrown into folds with villous projections, and infiltrated with inflammatory products. In the chronic inflammations, pannus-like growths may extend over the articular surfaces from the periphery, and there may be hyaline or fatty degenerative changes, or the deposition of cartilage or bone within the synovial membrane. Static defects may cause relaxed lateral ligaments with a less stabile joint, and therefore increase susceptibility to injuries and toxins.

I shall not attempt to go into the causes of chronic arthritis. When we speak of chronic arthritis it is important to specify which particular type we have reference to, as there appear to be at least 3 distinct types, each having a different cause. Data on procedures, such as the removal of foci of infection, are of no value unless the particular type of arthritis under consideration is specified. For example, if we were removing foci of infection in those types of arthritis probably caused by trauma or strains, our results would naturally not be encouraging, and in reporting our failures we would condemn the procedure as having no value in the treatment of chronic arthritis in general; while there is no question as to its value in the treatment of the infectious type. Similarly, all types of arthritis are not accompanied by marked changes in the synovial membrane, and it is irrational to expect favorable results from synovectomy in all such joints. A discourse on synovectomy in chronic arthritis is therefore of no value unless we are able to recognize the type for which we are proposing synovectomy. This is not always easily determined, as there are mixed types which can not be accurately classified.

It is unfortunate that there is no commonly accepted classification or nomenclature. There are, or have been, at least 14 different classifications each having its own adherents. Until there is agreement as to etiology there will continue to be different classifications, thus causing the utmost confusion. It is necessary to be familiar with the different classifications if we are to interpret reports intelligently. For example, when Ely speaks of Type 1, he has reference to the infectious or atrophic type; while Fisher, in speaking of Type 1, refers to the hypertrophic type. The importance of a standardized classification is therefore apparent.

In this country probably the most commonly accepted classification is that which recognizes 3 distinct types: the infectious, the atrophic or rheumatoid, and the hypertrophic or osteoarthritic. We shall not enter into a discussion of the etiology of the different types of arthritis. Suffice it to say that the infectious type is clearly caused by the spread or the absorption from some source of infection. There may or may not be an actual invasion of the joint structures.

The evidence is not conclusive that the atrophic and the hypertrophic types are infectious in origin. The rationale of synovectomy is either the removal of the focus of infection within the joint itself, or the removal of the sources of mechanical irritation. For the present, our indications must therefore be confined to the infectious type, or to any type in which large synovial fringes or cartilaginous bodies are aggravating the inflammation by forming obstacles to motion.

INDICATIONS FOR SYNOVECTOMY

Careful selection of cases is necessary. The disease must be localized in one or a few joints,

and the disease must be quiescent. The object of synovectomy, as in other forms of treatment, is first, to relieve the patient from pain; and second, to restore the maximum degree of function. Although a focus of infection may be removed by synovectomy, and symptoms in other joints may be relieved thereby, I believe that further work and observation of cases are necessary before we are justified in doing a synovectomy merely to remove a focus of infection for the benefit which may accrue to other joints. Conservative treatment demands, at least for the present, that the operation be confined to the removal of chronically infected synovia for the benefit of that particular joint; to those cases in which the synovial changes are of sufficient degree to cause an actual impairment of motion; or to cases in which motion causes further irritation, congestion, or proliferation of the synovial membrane or fat pad. Of course, before synovectomy is resorted to, the commonly recognized foci of infection should have been investigated and treated, and physiotherapeutic measures must have proved ineffective.

If inflammation is still acute, extensive dissection may result in such a degree of reaction of tissues as to produce an extensive scar formation which will limit motion. It is difficult clinically to determine quiescence, and errors in judgment are apt to occur. It was common experience in the infected war wounds that even after healing of a wound had existed for months, extensive traumatism of the previously infected tissues resulted in an acute flare-up of a dormant infection. The following case is illustrative:

C. T., age 39 years, foreman, had "rheumatic fever" 22 years ago. The onset began with pain and swelling in the right wrist and right knee. The pain in the wrist disappeared after 2 days, but the patient was confined to bed for 8 weeks because of a painful and swollen knee. He had no further trouble, except a persistent slight swelling, until 18 months ago, since which time the knee has been painful, and the swelling more pronounced. He had been unable to work for the past 3 months because of pain in the knee.

Examination on December 7, 1925, showed that there was a very marked swelling about the knee with a moderate increase in joint fluid. There was a slight elevation of local temperature over the anterior aspect of the joint, but no tenderness. There was painless motion between 100 and 160 degrees, but when motion was forced beyond these limits, he complained of severe pain. There was a marked joint crepitus. There were no clinical signs of disease of the central nervous system. The Wassermann test was negative. The rœntgenogram is shown in Figure 1.

Synovectomy through the split patellar incision was done on December 10, 1925. The markedly thickened synovia was excised as completely as possible, together with the thin and fibrous semilunar cartilages. Buried within the synovia were masses of bony tissue. The microscopic examination showed the synovial membrane to be strikingly thickened by granulation tissue richly infiltrated by wandering cells, mononuclears, and polymorphonuclears. There were many plasma cells. In places there were structures resembling lymph follicles.

About 1 week after operation there was a distinct elevation of local temperature about the entire knee. The patient was discharged from the hospital on the eighteenth day with the wound healed by first intention, but with the local temperature still elevated. One month after operation there was slight redness and local warmth about the entire knee, and only about 20 degrees of motion. He returned to work 3 months after operation with practically no pain, and with 40 degrees of motion between 130 and 170 degrees. He has continued to work steadily, has had no pain, and now has about 50 degrees motion. He is well pleased with the outcome, even though he has less motion than formerly.

Although at the time of operation, considerable roughening of the articular surfaces was noted, the resulting decrease in motion is not attributed to the destruction of joint cartilage. There was local heat before operation which became decidedly more pronounced after operation, with considerable pain on active and passive motion. This type of case, although relieved from pain, would seem to indicate from the microscopic appearance of the synovia that a lessened range of motion may be expected.

It is also to be remembered that cases of a low grade synovial tuberculosis may not be suspected clinically, and may be of long standing. If there is any question as to the accuracy of diagnosis, excision of a piece of synovia for laboratory diagnosis is essential. Figure 2 is the rœntgenogram of a patient, 26 years old, who had only a moderately painful and stiff knee of 8 years' duration. Although the rœntgenogram showed no bone atrophy, and there was no apparent destruction of the articulating cartilage, the microscopical examination of a piece of synovia removed for diagnosis revealed tuberculosis.

Steindler (4) emphasizes the important point that it is difficult to judge the degree of cartilage destruction, and in the event of considerable erosion of cartilage with pannus formation, a certain latitude of action should be reserved by the operator, and the indication of simple synovectomy should be changed to fusion and stabilization.

Traumatic cases. Extravasations of blood in the synovial membrane as a result of trauma may set up an inflammatory reaction consisting of small mononuclear and perivascular infiltration practically identical to that caused by infection. Sprains of lateral ligaments, repeated dislocations of the semilunar cartilages, loose bodies, or enlarged fat pads which are caught between the articulating surfaces, may cause permanent

damage to the synovia resulting in disability even after the original offending factor has been removed. The anterior aspect of the knee is sensitive, and extension of the knee is painful and limited.

Under this heading may be mentioned hypertrophied infrapatellar fat pads. Through trauma, or from the absorption of toxins, the fat pads become swollen. On full extension of the knee the enlarged fat pad becomes pinched between the articulating surfaces. As a result of this mechanical irritation it becomes still further swollen and congested, and therefore still more likely to be pinched. The patient complains of pain at the infrapatellar region on extension of the knee, and there is tenderness on each side of the patellar tendon. Because of the pain, an early atrophy of the quadriceps muscle develops, and the fat pad is not protected by the action of this muscle from injury. Thus, a vicious circle follows. The treatment of this condition is not fixation—as this causes a further atrophy of the quadriceps—but measures to prevent complete extension of the knee by means of suitable apparatus. If, after a reasonable length of time, recovery does not follow, it is conservative treatment to remove the offending fat pad before irreparable damage to the synovial membrane results. This may be done through lateral incisions.

The writer has not found the Jones knee cage brace a satisfactory apparatus to check movement of the knee short of complete extension. Even very tight strapping, both above and below the knee, does not prevent it from slipping downward so that the hinge is not opposite the axis of motion in the joint. The tight bands also cause swelling about the knee and leg through passive congestion, and the pressure of the straps over the quadriceps causes an atrophy of this muscle. Patients also object to a brace extending to the sole. Figures 3, 4, and 5 show a brace which has proved to be very satisfactory in checking complete extension of the knee. It remains in place and is comfortable to the patient. Tight lacing is not necessary.

Chronic inflammation. There is a second group of cases in which the bone changes may be slight or absent. The synovial hypertrophy becomes extreme, forming pedunculated growths. This is commonly called villous arthritis. The synovial membrane is markedly hypertrophied, and is thrown into folds or villi, thus giving the surface a velvety appearance. Clinically this type of joint shows more or less swelling with increase in fluid, thickened capsule, and a doughy consistency. There is marked grating or joint crepitus. The villi project themselves between the articular margins, and are thus subject to repeated traumata. This villous hypertrophy is not nearly so prominent a feature in the hypertrophic arthritis as in the atrophic and infectious arthritis. Its effect is to cause mechanical obstacles to free motion which, of course, must aggravate the existing inflammation. A vicious circle again develops, and the benefit of removal is evident. In this type of case, excision of the entire synovial membrane is indicated, and if the semilunar cartilages are thin or frayed out, these also should be excised. It is just a question of degenerative changes from this condition to that of the next group, or osteochondromatosis.

Figure 6 is the rœntgenogram of a man aged 46 years, who for the last 6 years complained of pain and stiffness in the right knee. There was an extreme doughy swelling about the knee, and very marked grating on movement. There was only 40 degrees motion between 110 and 150 degrees. There was no acute tenderness. For almost the entire past year he was able to work only at a sitting job. The rœntgenogram shows but little bone change. He returned to work at a standing and walking job in an automobile factory 7 weeks after operation with 60 degrees motion, and has been working steadily ever since. At present he has 90 degrees motion between 90 and 180 degrees.

Osteochondromatosis. In osteochondromatosis there are numerous cartilaginous bodies of various sizes within the joint. They have their origin in the synovial membrane. They may be free or attached by a pedicle, or may be completely hidden from view, buried within the thickened synovial membrane. It is therefore impossible to remove all of these bodies without removing the synovial membrane. Even if this were possible, it is likely that others would form to give trouble later.

Hypertrophic arthritis. Loose bodies in the joint may form from fractured nodules, generally from the femoral and patellar surfaces. These are commonly called joint mice. Since their origin is not from the synovial membrane, synovectomy is not indicated unless secondary synovial changes as a result of the repeated traumata caused by these joint mice are sufficient to give trouble even after they have been removed.

Synovectomy should not be recommended as a procedure to increase the range of motion when the patient's chief complaint is stiffness, and not disability because of pain. However, the removal of the source of irritation and infection is expected to result in a greater range of motion. Complete

removal of the synovial membrane is bound to result in a more or less scar formation which may limit motion, but if the disease is mainly confined to the synovia, without marked destruction of cartilage, an increased range of motion may be expected. It is not safe to promise the patient a greater range of motion, because of the difficulty in determining quiescence, or the degree of cartilage destruction, as mentioned before. Swett, however, advises the operation in joints in which the process is still active.

Synovial membrane regenerates after synovectomy. The experimental work by Key (3) showed that new synovial membrane is formed by metaplasia of underlying connective tissue. His observations have been confirmed by Wolcott (6), who, in addition, has demonstrated the regeneration of the infrapatellar fat pad.

DESCRIPTION OF THE OPERATION

A longitudinal incision is made over the anterior surface of the knee, directly in front of the patella. The incision extends upward, and is carried through the quadriceps tendon, and downward through the patellar tendon. The patella is split or sawed through vertically just medial to the middle line, and the two halves are retracted widely, giving a very complete exposure of the joint. It is best to do the operation under a tourniquette, as the chronically inflamed tissues bleed freely, and hæmorrhage is difficult to control. It is also advisable to prevent bleeding as much as possible so as to minimize frequent sponging which may injure the delicate articulating cartilage. Sponging is best done by soft pledgets of cotton.

The entire synovial membrane is then carefully dissected away down to the joint capsule, and the infrapatellar fat pad removed as well. If the cartilages are damaged, these are also removed.

Before closing the wound, the tourniquette should be removed, and the greatest care taken to control hæmorrhage. If blood is left in the joint it organizes and forms adhesions which will prevent free motion and cause pain, and may cause a destruction of the articulating cartilage. The wound is carefully closed in layers. It is not necessary to pass sutures through the patella. Interrupted chromic sutures through its thick and tough periosteum is sufficient.

For the first 4 days the joint is kept at rest, mainly to prevent intra-articular bleeding which forms adhesions. A Thomas splint which has been provided with a hinge at the knee joint is applied with moderate traction. Active motion is insisted upon, gradually increasing in range from day to day. It is important that complete extension be at all times possible. If motion is pushed too rapidly, this may be lost as it is easier to flex the knee than extend it. After 2 weeks, crutches are allowed with light weight-bearing. Much more rapid progress is made when the patient is up and can force flexion by placing his foot on the floor. I do not believe that passive motion is of much assistance, but early massage to the quadriceps muscle hastens recovery because of the atrophy which follows opening the joint. Too vigorous treatment does harm as it leads to irritation, muscle spasm, and a loss in the gain of motion. Forcible manipulation under a general anæsthetic should not be necessary, and one should be extremely cautious in its use. Gentle manipulation may be permissible after the end of 2 weeks but the joint should be put through its range of motion only once. Great care must be used to avoid causing any active inflammation, as the inflammatory products are likely to result in still more extensive formation of adhesions. As a rule, crutches may be discarded at the end of the fifth week.

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AN ANOMALY OF INTESTINAL ROTATION

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EXAMPLES of abnormal position of the abdominal viscera have been reported at various times by surgeons and anatomists but only lately has their importance been adequately appreciated.

A failure of the third stage of rotation of the mid-gut loop, in which the ascending colon and cæcum normally lose their primitive mesentery and by the process of zygosis become fixed to the posterior wall of the right loin and iliac fossa, is by no means uncommon and varies in degree from an unduly mobile cæcum to a floating cæcum and ascending colon which retain their primitive mesentery, a subject which has recently been fully treated by Waugh (4).

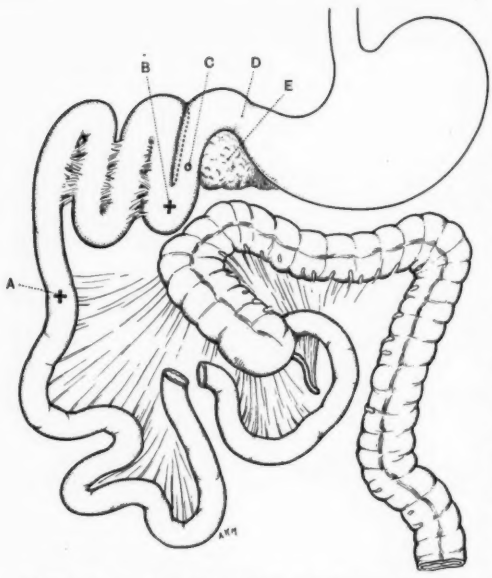
A case of this kind I recently came across in the course of an exploratory laparotomy on a man of 76 suspected to have a growth of the ascending colon. A cæcum and ascending colon with a complete mesentery were readily brought out on the surface, and the supposed growth proved to be a mobile kidney. His symptoms of discomfort in this situation were only of 3 months' duration and it appeared probable were due to the kidney having recently become mobile owing to loss of fat. An interesting feature was that the mobile cæcum and ascending colon had never caused him trouble in the course of a long and active life. The case here reported is one of failure of the second stage of rotation. It is the first of its kind that I have come across or at any rate recognized and, as the condition is decidedly rare and also somewhat puzzling when found, it appears worth recording in some detail.

Mrs. A. N., aged 57 years, the mother of four children, was sent to me with the following history. For many years she had suffered from epigastric pain shortly after meals and a feeling fullness and flatulence which were relieved by the belching of wind or by the removal of her corsets. During the past 6 weeks her symptoms had become greatly aggravated, vomiting had supervened, and she was practically unable to keep down any food. It appeared to me to be a case of cholecystitis (which opinion I subsequently heard from her doctor was also his own) and I advised operation regarding which she was at first most averse. However, her symptoms became so distressing that she urged that the operation be performed earlier than had been fixed and, I was informed that the night preceding the operation the belching of wind was incessant.

Laparotomy by a right upper paramedian incision disclosed a normal appearing stomach and first stage of the duodenum. The gall bladder contained no stones but as there were some yellow streaks of lipoid material in its walls and a deposit of fat at the neck it was removed without any difficulty. A mobile cæcum, with a complete mesentery, was brought up into the wound. The ileum entered it on the left side, normally, and the appendix showing no evidence of disease was returned into the abdomen. It was then noticed that a large amount of small intestine lay to the right of the cæcum and ascending colon and when these were traced up it was found that in the right hypochondrium there was a series of U-shaped loops plastered on to the posterior abdominal wall. They were kinked, moderately dilated, and fixed to each other by membranous adhesions. The hand passed below the transverse colon failed to find the duodenojejunal flexure in the normal situation. An attempt was then made to unravel the above mentioned adherent coils when it was found that they comprised the second and third stages of the duodenum and passed insensibly into the jejunum. This condition shown in the diagram was verified by a limited examination postmortem. The superior mesenteric artery did not cross the duodenum but ran down to the right of the cæcum and ascending colon. As it then became apparent that her symptoms were in all probability due to a form of chronic duodenal ileus, an attempt was made to relieve this by anastomosing the first free portion of jejunum to what corresponded to the second stage of the duodenum and it appeared that this had been done without causing any kinking. However, regurgitant vomiting followed the operation, persisting in spite of washing out the stomach so that it became necessary to re-open the abdomen 2 days later. Although the efferent limb was kinked at the site of anastomosis and the drainage of the loops was not efficient, they were only moderately dilated and the stomach not at all, but there was great distention of the whole of the remainder of the small intestine which appeared to be in a condition of paralytic ileus. A jejunostomy was performed, but the patient's symptoms were not relieved and she succumbed on the following day.

The great distention of the distal small intestine suggests that a partial torsion may have occurred as in the condition described by Dott (2) as mal-rotation, but in the limited examination permitted postmortem, this could not be determined, and in the course of an operation such complicated conditions are often difficult to determine with accuracy. As regards the original operation of jejunoduodenostomy, an anterior gastrojejunostomy would have been far preferable and might have been attended with a different result. It is for this reason that in obscure abdominal conditions in which no very definite cause is found when the abdomen is opened, their possible presence should be borne in mind and the most appropriate method of dealing with them carefully thought out.

A reference to the diagram shows two U-shaped coils. In the angle between the descending limb of the first and the pyloric portion of the



A, Site of anastomotic opening in jejunum; *B*, site of anastomotic opening in duodenum; *C*, situation of bile papilla; *D*, pylorus; *E*, head of pancreas.

stomach lay the head of the pancreas, and the common bile and pancreatic ducts opened into the middle of this limb in the normal situation.

In this connection the report of a case of "Extensive Diverticulosis Without Symptoms" by Norman Corkhill (1) is of great interest. I quote the portion which is relevant to this case: "The duodenum with the superior mesenteric artery on its inner side turned back on the head of the pancreas in the shape of a double S. The duodenojejunal flexure was at McBurney's point, the mesentery running thence upward to the left. The mesenteried cæcum, which was entered by the ileum from the right, was slightly to the left of the midline in the upper umbilical region."

These two cases, my own and that reported by Corkhill, are examples of an anomaly of the second stage of rotation of the mid-gut loop, that portion of the intestine extending from the bile papilla to the region of the splenic flexure. Anomalies of intestinal rotation form the subject matter of a paper by Dott (2), in which after describing fully normal rotation, he cites three cases, one in a man of 68 with reversed rotation, one of non-rotation with volvulus in an infant, and one also in an infant of a similar nature.

Keith also briefly mentions these anomalies (3). The anomalies of the second stage are (1) non-rotation, (2) reversed rotation in which instead of the cranial extremity of the bowel first entering the abdomen in the counter-clockwise direction the caudal extremity passes in first, the rotation being clockwise and the superior mesenteric artery lies in front of the transverse colon. It would appear that the first variety may cause no symptoms (Corkhill's case), or symptoms may be due to chronic duodenal ileus from duodenal kinking (my own case) or possibly partial torsion of the U-shaped loop may occur and rectify itself or else may give rise to a complete volvulus as in the condition described by Dott as mal-rotation.

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EDITORIALS

SURGERY, GYNECOLOGY AND OBSTETRICS

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DIAGNOSIS, THE CRUX OF THE PROBLEM OF ACUTE OSTEOMYELITIS

THE comparison between acute appendicitis and acute osteomyelitis is not a new one. More than one writer has pointed out that the diagnosis of one condition is no more difficult than the diagnosis of the other, and that prompt treatment is equally important in both. Unfortunately, however, the comparison ceases at this point. In the great majority of cases today acute appendicitis is promptly diagnosed and promptly treated by the correct surgical measures. But acute osteomyelitis is diagnosed correctly only in a relatively small percentage of cases and it is treated so largely by medical methods that more than one observer—the writer is numbered among them—states without qualification that acute osteomyelitis is practically never seen in its initial stages in the surgical wards of public hospitals.

The general practitioner is blamed unjustly for many things, but the tragedies of acute osteomyelitis only too often lie at his door. He sees the patient first, he makes the diagnosis, in a regrettably large number of cases he makes it incorrectly, and he uses temporizing medical measures (chiefly the administration of salicylates) at the only time when benefit can be expected from anything short of a mutilating operation. Then when the damage is done, when the true condition is revealed, the patient is turned over to the surgeon, who is expected to work the miracle of a cure in the face of extensive bone destruction and lessened constitutional resistance. The giving of a cathartic has complicated many a simple appendix and in exactly the same way the medical treatment of osteomyelitis and the resulting loss of time may convert a relatively simple condition into one which jeopardizes both life and limb.

The records of one New Orleans hospital for the last 6 years show that in 25 per cent of the cases the patients who were later proved to have the disease were admitted with no diagnosis at all, in 50 per cent the diagnosis was incorrect, and in only 25 per cent was even a tentative diagnosis of osteomyelitis made, in spite of the fact that all of the latter group exhibited fairly advanced stages of the disease. It is obvious that a condition which exhibits a 75 per cent error in diagnosis is not likely to result in a high percentage of cures.

The astonishing part of this situation is that the diagnosis is not difficult to make if only the possibility of the disease be borne in mind. The clinical picture is perfectly clear-cut. Acute osteomyelitis occurs most often in young children and there seems to be a definite seasonal incidence. The summer incidence may be attributed to the prevalence then of minor skin infections, the fact that swimming is a popular amusement, and the

likelihood that chilling may follow getting out of the water. The winter incidence is easily explained by the prevalence of tonsillitis and ordinary colds. It is admitted that the disease most often originates in either local skin infections or in infections of the cavities of the head; traumatism is not an important consideration except in so far as it assists in the localization of the infection by providing a suitable field for the growth of the bacteria.

The first symptom is persistent, localized pain near, not in, a joint. Then comes a chill, a temperature of 103 degrees F. or higher, the usual manifestations of toxæmia, and a definite leucocytosis. Such a syndrome is almost pathognomonic, and it might be well to add that a negative X-ray examination at this stage, paradoxically enough, confirms the diagnosis; by the time gross changes can be demonstrated radiologically the disease is no longer in the early stage.

The localized pain should be enough to eliminate such diagnoses as intestinal upset and typhoid fever. Acute articular rheumatism and acute infectious arthritis offer more reasonable grounds for confusion but even here the differentiation should not be difficult. In the former disease there is a more gradual onset, less constitutional reaction, and a definite localization of the pain in the joint rather than merely in its neighborhood. Most important of all, unlike osteomyelitis, it is practically always a multiple affair involving several joints. In arthritis there is more joint fixation from muscle spasm, and the swelling of the synovial joint membrane is in marked contrast to the practically negative physical findings of acute osteomyelitis in its first stages.

The disastrous consequences of an incorrect diagnosis are only too well known but they were recently brought home very strikingly to the writer by the fact that on his service at Charity Hospital four patients were under treatment at the same time whose combined disability, thanks to the type of treatment they had received initially, totalled exactly one hundred years. From an economic standpoint, if from no other, such a waste should not be tolerated.

The necessity for early treatment is clear if the essential pathology of osteomyelitis be considered. It is primarily a metastatic or blood-borne disease, originating, as has been pointed out, in some minor skin infection or some infection of the cavities of the head. The septic infarct, which is always small, is arrested by the smallest capillaries of the body, those of the metaphyses of any of the long bones, and a true bone abscess forms. Unyielding bone cannot swell as can the soft tissues of the body, therefore bone inflammation can end in only one way, necrosis from local anæmia. If an avenue of escape is not opened, the necrosis becomes more extensive, the resulting toxæmia becomes more extreme, a terminal septicæmia may result, and the patient may lose his life as well as his limb. If he survives, radical treatment is necessary, varying all the way from simple removal of the sequestrum to complete excision of the shaft of the bone.

The safety and simplicity of treatment in the initial stages of the disease is in marked contrast to this tragic picture. Limitation of the process can be achieved in practically every early case by simply boring small holes in the cancellous bone structure with an ordinary carpenter's gimlet. Such a procedure, done under aseptic precautions, can do no possible harm even in the occasional case in which the diagnosis has been made incorrectly, while in the great majority of cases it will mean the preservation not only of function but often of life itself.

URBAN MAES.

THE CHANGING CONCEPT OF THE TREATMENT OF SYPHILIS

FOR decades preceding the recognition of the spirochæta pallida by Schaudin and Hoffman and the synthesis of salvarsan by Ehrlich, the treatment of syphilis was simple and uncomplicated. However, since 1915 there has been a progressive advance in syphilotherapy. In a surgical practice, approximately one syphilitic will be found among 10 or 12 patients; therefore the therapeutic trend of syphilis is of significance to the surgeon. Salvarsan, now called arsphenamine, controls the infectious lesions of syphilis rapidly and is essential in public health work. The more benign manifestations such as cutaneous or osseous gumma likewise melt rapidly following its use, but the more vital the organ involved, the less complete is the recovery; as, for example, the cardiovascular and central nervous systems. The drug relieves the symptoms and arrests the progress of syphilis when used in conjunction with other metals in from 75 to 80 per cent of cases, and it is for the remainder of this group that new methods of treatment are sought.

The various modifications, such as neoarsphenamine and sulpharsphenamine, and the newer methods of administration have decided advantages in certain cases, but have not proved arsphenamine to be a panacea. The original conception that one dose cures was discarded shortly after its advent, and we now know that rarely will 100 doses cure when 20 or 30 have failed. In contrast, it has been suggested that the intensive use of salvarsan in the early course of the disease predisposes to the development of neurosyphilis, but accumulated evidence does not uphold this. As the shortcomings of arsphenamine were recognized, newer remedies were sought to prevent the serious sequelæ of the disease. Mercury by inunction or intramuscularly was revived and was used in conjunction with arsphenamine because it had been shown that mercury by mouth was wholly inadequate to control the disease. At the present time certain syphilographers resort only to the use of mercury by inunction during the early phase of the disease, believing that the allergic influences, that are stimulated by rubbing, materially aid in control of the infection. The use of the iodides has always been advocated in the late form of the disease, without knowledge, however, of what is accomplished, or how.

Various other metals have been used in an effort to find a substitute to fulfill the faith originally placed in salvarsan, and bismuth seemed most closely to approach the ideal. Its use intramuscularly does not supplant the arsphenamines, but it has possibly a higher therapeutic efficiency than mercury. Continued experience with bismuth may reduce the enthusiasm attending its present use.

The intensive application of arsphenamine, mercury, and iodides will cure approximately 75 per cent of patients with acute syphilis who follow the therapeutic regimen outlined for them. The time, energy, and expense entailed in such a course of treatment is greater than the majority of young adults, who are most prone to acquire the disease, will expend in ridding themselves of the infection. Hence the frequency of clinical relapse in acute phases of the disease.

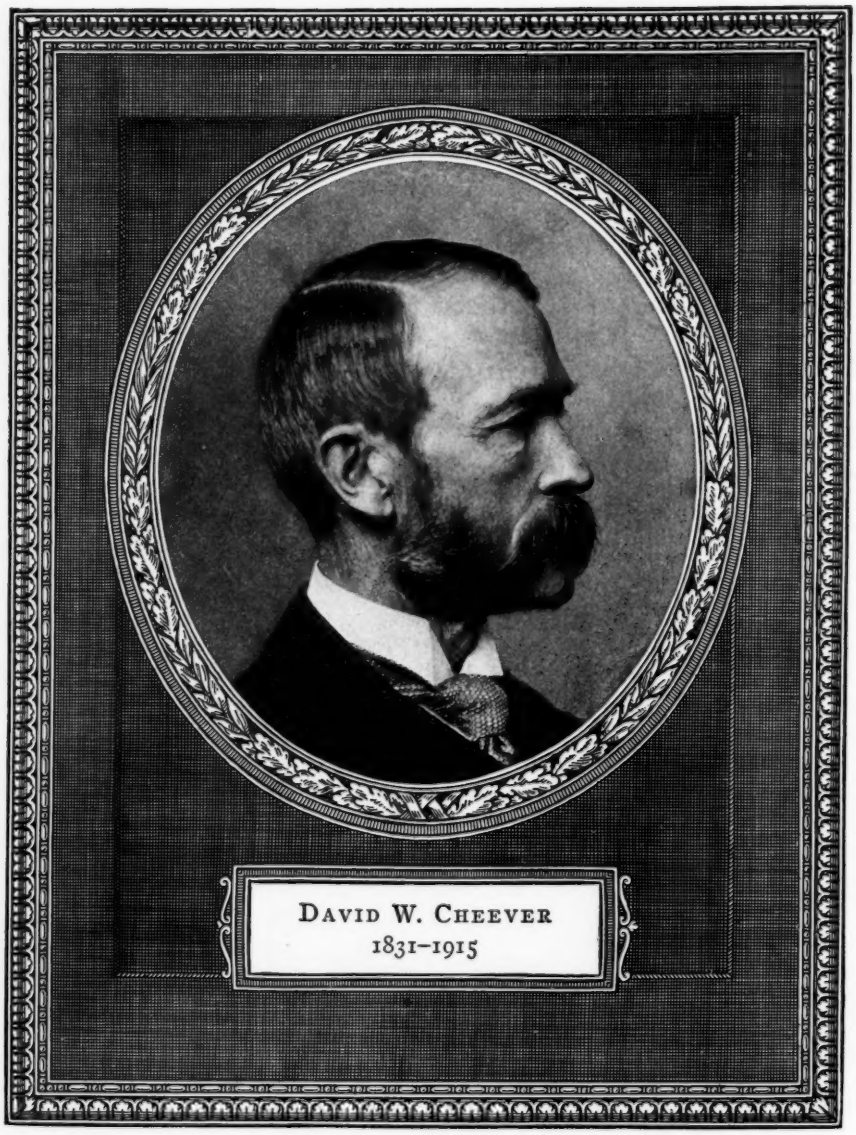
The period of latency, varying from a few years to twenty years or more, is dependent on the patient's resistance to the infection. In contrast, the patient in whom paresis or syphilitic aortitis develops within three years after the infection is acquired lacks a defense reaction mechanism. In other words, the type of soil on which the spirochæta pallida falls determines the crop of complications to be

reaped. Unfortunately arsphenamine influences this soil but slightly.

Wagner von Jauregg suggested the use of malarial fever in the treatment of general paresis because it had been known for many years that a patient with psychosis often improved after a period of fever. It has been shown by investigators in this country and in Europe that the production of fever has caused remission in about 40 per cent of cases of general paresis treated by this method. It should be borne in mind that a disease which produces symptoms by destruction of tissue will not clear up without leaving symptoms or scars, and so the results of this new treatment should be graded by the economic good that is accomplished for the patients, and not by the disappearance of the objective signs of the disease. To condemn the method because the Argyll-Robertson pupils or the sensory changes or the deep reflexes remain unchanged is unfair. If the patient is restored to his former occupation or if more menial work permits him to support his family, the method is worthy of further trial. The remission produced in 40 per cent of the patients treated compares favorably with the remissions that have occurred spontaneously for years in 12 per cent of patients with general paresis.

The mechanism by which a series of from twelve to fourteen attacks of malarial chills and fevers produces this remission is not understood. It has been suggested that the temperature itself has had a prominent part in the result or that the plasmodium vivax stimulated an immunity reaction against the spirochæta pallida. Assuming that both of these forces are essential, nevertheless some other influence must be at work, and of these no doubt allergy or "umstimmung" is the outstanding factor.

The abortive cure of acute syphilis is occasionally unsuccessful. The results in the treatment of the secondary and latent forms are influenced by the patient's resistance and his application of the therapeutic measures suggested. The late visceral complications, if recognized early, are amenable to treatment in a high percentage of cases, and the progress of the involvement of the nervous system may be arrested in proportion to the time at which treatment is started. If paresis exists, remission may now be produced in 40 per cent of the cases by treatment with malarial fever. The modern syphilographers, having been disappointed by some of the failures of arsphenamine are redirecting their efforts to the stimulation of the individual defense mechanism rather than the continual flooding of the patient's blood by intravenous medication. In the fervor that attended the introduction of salvarsan, followed by the misconception that since one dose would not cure perhaps 40 or 50 or more would, the patient's mechanism of defense was forgotten; also no doubt the belief that specific strains of the spirochæta pallida existed that exerted special affinity for nervous tissue or skin or viscera, helped to swing the pendulum forcibly toward the concept of specific drugs and specific cures. The modern syphilographer is now anticipating the resistance mechanism and a means of stimulating it, rather than endeavoring to overwhelm the spirochetæmia by the intravenous injection of massive doses of arsenic and mercury. PAUL A. O'LEARY.



DAVID W. CHEEVER
1831–1915

MASTER SURGEONS OF AMERICA

DAVID WILLIAMS CHEEVER

I AM glad to have the opportunity of presenting a biographical sketch of one of New England's great surgeons. When I first went to Boston as a young man in surgery, I had the pleasure of attending Dr. Cheever's lectures and clinics, where I learned lessons of enduring value. Dr. Cheever was a quiet, modest man, at once a brilliant operator and a precise, sound, and conscientious surgeon. He made notable contributions to science which surgeons of this generation do well to study. His lectures, which have been reprinted, are as readable and as much to the point today as when they were first issued in 1894. They present in graphic language a sequence of events in pathological conditions that give insight not only into the character of disease and its effect on the patient, but also its relation to surgical conditions in general. W. J. MAYO.

THE Harvard Medical School, and the science and art of surgery in New England were widely influenced during the last third of the nineteenth century by David Williams Cheever. He was of Puritan stock, descended through a line of ministers, teachers, and doctors from Ezekiel Cheever who came from Canterbury, England in 1637, taught school for 70 years in Boston and vicinity and became one of the earliest and the most famous of the masters of the Public Latin School. Four of these ancestors were graduates of Harvard College and two were physicians—his grandfather Abijah Cheever of Boston, a surgeon in the Revolutionary War, and his father Charles Augustus Cheever, who in a small New England town practiced medicine and surgery, attracted students and with them dissected cadavers in his attic, prepared skeletons and wax injections, and did novel operations after reading descriptions in the scanty literature of the period and practicing on what material he could obtain.

The son was born in Portsmouth, New Hampshire, November 30, 1831. His life was that of the average New England boy. He remembered helping his father in surgical emergencies before the days of anæsthesia. He graduated from Harvard College in 1852, still uncertain as to his career, since his father opposed medicine and he himself leaned toward a literary calling. In this doubt an opportunity to study and travel on the Continent presented itself, and association with American medical students in their hospital visits brought the realization

that only medicine would satisfy him. He returned and plunged into the Harvard Medical School. Let those who insist on prolonged and rigid pre-medical requirements take note that this man would probably have been lost to medicine if early decision had been necessary!

Picture a leading medical school of 1856. Attendance at three courses of lectures was required—each course consisting of five lectures a day for 4 months. The clinical work consisted of "walking the wards" of the Massachusetts General Hospital once a week in medicine, and once in surgery, and of attending a day of showy public operations. In the remaining 8 months the student attended extramural lectures or apprenticed himself to a practicing doctor, or loafed or worked at other things. The next year the same course of lectures was repeated, and the next; then a perfunctory examination and a degree. There was no laboratory work except in anatomy and that was not required, but the earnest student could dissect the three parts assigned to him and bargain and dicker for more. Four of the eight professors attracted Cheever: Storer in obstetrics, Clarke in materia medica, Henry J. Bigelow in surgery, but preeminently Oliver Wendell Holmes in anatomy. To the latter—witty, brilliant, scholarly—he gave allegiance and he dissected and dissected and dissected. Holmes noticed him, to his later advantage, as we shall see.

Four opportunities each year for interne service were available—two as medical and two as surgical "house pupils" at the Massachusetts General Hospital. Appointment was not by examination but by solicitation of the trustees. Was it likely that a country boy without influence or friends would be chosen? Cheever thought not, and his soul rebelled at possible rejection without trial. He apprenticed himself to the physician of the State Almhouse Hospital on an island in Boston Harbor for a year, and a panorama of the needy, destitute, and criminal sick passed before him, affording a mixture of general medicine, obstetrics, a little surgery, the care of children, contagious diseases, skin diseases, and venereal infections. He compounded medicines, improvised apparatus, and was given a free hand with privilege of reference to his chief when he wished. It was good preparation for general practice.

So he hung out his modest shingle in Boston, waited 2 weeks for his first patient, and collected four hundred dollars the first year. He kept the pot boiling by writing essays for the *Atlantic Monthly* and the *North American Review;* he accepted the position of physician to the small-pox hospital during an epidemic and conducted it with as little as possible publicity among his patients and friends. And Oliver Wendell Holmes remembered the zealous dissector of the class of 1858, and when the demonstratorship of anatomy became vacant he offered it to him. Thus began 33 years of teaching in the Harvard Medical School.

For 8 years he labored hard at the demonstratorship, making all of the lecture dissections for Holmes, revolutionizing the teaching in the dissecting room, and

instituting competitive dissections and quizzes over the cadaver to quicken a dead subject. This constant work on the cadaver turned his mind to operative surgery which he diligently practiced, but without much chance to apply it on the living, as he had no hospital appointment. The Civil War found him with a wife and small children dependent on his daily work. He gave what service he could as acting assistant surgeon in Washington. Army medical inspectors detailed to protect the wounded from the attentions of unskilled and over-confident surgeons, appraised his work and offered him the control of a large hospital, which had to be refused.

In 1864 when he was 33 years of age, surgical opportunity knocked at his door and found him prepared. He was appointed surgeon to the new Boston City Hospital, the youngest member of the staff. On June first the hospital opened its doors, and on that day Cheever did the first operation in the theater under the dome. It was an excision of an extensive epithelioma of the lips and cheek. There was no antisepsis or asepsis, no clinical thermometer, no hypodermic syringe. But the frequent dressings were with chlorinated soda—a pretty good antiseptic! The silk ligature on the facial artery came away on the sixteenth day and the patient recovered.

There followed 50 years of service to the hospital as visiting surgeon and consultant, which constituted the most important single factor in establishing its high reputation among similar institutions. Cheever had a high ideal of the obligations of the hospital clinician to the community and to the profession. The surgical staff under his leadership worked like demons to secure a place in the sun. He reported cases, conducted voluntary clinics and ward visits for students and doctors, and instituted Sunday conferences for all members of the staff. Competitive examinations for house officers were introduced, a much-needed reform in Boston. Medical and surgical reports were issued, edited for 25 years by Cheever and a medical associate. He called these the history of his professional life. It was difficult to attract students because the vested interests at a rival and already venerable hospital monopolized the teaching hours. But students are apt to be independent and seek knowledge wherever it may be obtained. The demonstrator became assistant professor of anatomy, and gave courses in regional anatomy. The Czar of surgical Boston objected that such courses were the prerogative of the surgical department (though no one had thought of giving them before!) and stopped them with no light or courteous hand. Result: resignation, investigation by the Faculty, revelation, reinstatement and promotion to the position of adjunct professor of clinical surgery, with opportunities to give didactic lectures at the school, clinical lectures at the hospital, courses in regional anatomy, and to have a seat in the Faculty. Thus always may humiliation come to him that cannot brook an honorable young rival!

Those were great days. The chair of clinical surgery was established in 1875, and Cheever was its first incumbent. He established the weekly conference, a clinical report by a student with references to the history and literature of the subject, read before the assembled class and teachers. Henry J. Bigelow gave the didactic lectures in surgery, Cheever gave the clinical instruction. In 1882, on the resignation of Bigelow, Cheever was appointed professor of surgery in Harvard University—the pinnacle of surgical preferment in New England. In 1893, at the age of 62, fearful lest the years might impair his efficiency without his knowledge and mindful of this calamity among some of his senior colleagues, he resigned the professorship, to which succeeded J. Collins Warren. As emeritus professor he gave special instruction at the request of the students; he continued at the City Hospital in the rôle of consultant, and in 1903, at the age of 72, he did his last surgical operation.

During these years Cheever was a leader in New England medicine and his reputation was international. He originated some operations, and introduced others to this community. He was the first in America to remove foreign bodies from the gullet by œsophagotomy and his monograph on the subject is a classic. Now the operation is nearly discarded, since electrical illumination permits removal without incision. He did cæsarean section,—perhaps the first in New England. He had the first two consecutive successful ovariotomies in Boston, before the days of antisepsis. He did plastic displacement of the upper jaw for removal of pharyngeal tumors, he removed the malignant tonsil by external incision, he worked hard to perfect Wood's operation for the radical cure of hernia. He was well known abroad;—Ollier of Lyons corresponded with him about subperiosteal excision of long bones; Reginald Harrison of London about impermeable stricture; Holmes of St. George's Hospital about excision for coxalgia; Billroth of Vienna about the tonsil; John Wood of London about hernia. He became a foreign member of the Paris Society of Surgery.

It is hard for us to realize the handicaps under which this work was done. Anæsthesia was imperfect. There was no antisepsis or asepsis, no catgut ligature, no roentgen ray, no electrical illumination of cavities. Pyæmia, septicæmia, erysipelas, and hospital gangrene stalked like spectres through hospital wards.

Then came Lister's beneficent gift, and the whole aspect of surgery changed. As was said by a disciple, Lucas-Championnière: "Surgery has only two periods; first, that before Lister, and second, that since Lister." The new era found Cheever at the height of his powers and receptive, as always, to progressive ideas. He adopted Listerism—first the carbolic solution and wound irrigation, catgut ligatures, and then the carbolic spray under which the surgeon worked until his head ached and his hands became numb and even his urine bloody from the renal irritation. Then asepsis supplemented antisepsis, and the tremendous field of elective surgery, especially of the great body cavities was added to the older im-

perative work. Thus Cheever in his long life touched three great epochs: as a youth he helped his father operate before anæsthesia; in his early prime he struggled with wound infection before the days of Lister, and in his maturity he enjoyed the security and certitude of healing conferred by Lister's gift to humanity.

His operative work was based on painstaking preliminary study and diagnosis, well-nigh perfect knowledge of anatomy, familiarity with gross pathology, and careful review beforehand of every step and anticipation of every complication. Let the event be what it might, it found him ready. His manual dexterity was average; he himself did not think he excelled as an operator. He was imperturbable, steady, unruffled, but these qualities were due to iron control of a sensitive and high-strung temperament. His policy was of wise preparedness. "His foresight and forethought prevented mistakes, inspired confidence and insured favorable results." His wide experience in general practice gave him breadth of view and depth of judgment.

Thirty-three classes of Harvard medical students delighted in his teaching which after all was the field where he was unrivalled. Perhaps the genius of the old Master of the Public Latin School in Boston was dominant again in him. The demonstration of an anatomical dissection, of an operation, of a clinical problem or the conduct of a ward visit, were to him prized opportunties to teach his precious art to others. The didactic lecture—now justly disparaged in its usual form, was in his hands an important and acceptable instrument of teaching. It was carefully prepared beforehand, but delivered extemporaneously in short crisp sentences of Anglo-Saxon English, wholly without theatrical effect, but lucid, comprehensive, logical. Its principles and epigrammatic precepts remained fixed in the student's mind and guided his later practice. A young graduate, versed in short-hand took down the lectures as delivered, and later, with none but minor corrections, they were published in book form as *Lectures in Surgery*. In medical education he staunchly supported President Charles W. Eliot in raising pre-medical requirements, establishing a graded four-year course, and developing clinical teaching.

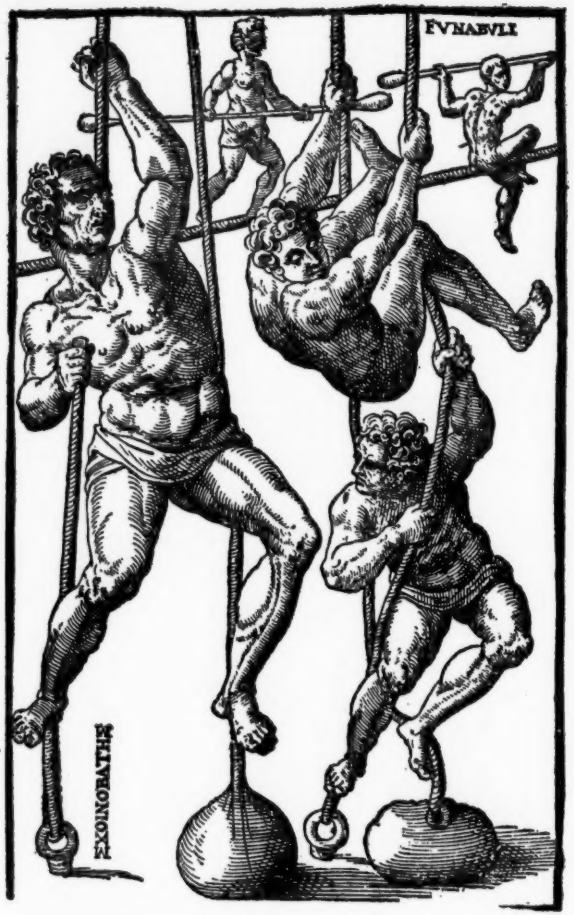
Cheever felt strongly the obligations of the physician to the community. His steady purpose is expressed in a reminiscent sentence from his pen: "I have tried to advance our profession." He wrote, lectured, published, supported medical societies, and actively abetted all measures looking toward the health of the community and the dignity and high standing of the medical profession. He fought quackery and medical imposture in all their forms. He helped dethrone the notorious coroner system in Massachusetts, worked for privileged medical communications, and frequently appeared before legislative bodies. He was president of most of the local medical organizations, including the Massachusetts Medical Society, and was the seventh president of the American Surgical Asso-

ciation, in 1888. For 12 years he served on the board of overseers of Harvard College. He was a member of the American Academy of Arts and Sciences, and an honorary member of the Philadelphia College of Physicians and other societies, and a foreign member of the Society of Surgery of Paris.

The personal impression made by Cheever was of a tall, slender, slightly stooping man, with reserved and somewhat grave demeanor, but with ready and responsive smile. Intellectual and moral vigor dwelt in a rather delicate physical tenement which he preserved by daily exercise and a mode of life temperate in everything but work. He revelled in the opportunity to dwell with Nature in his vacation and when fatigue and responsibility vanished he was light hearted and witty. With increasing leisure in later years he enjoyed travel, visiting the scenes to which his reading had introduced him. He succeeded in medicine because he loved his profession above all else but his family circle; he concentrated upon it during his active years all that he had of talent and energy. He loved especially the human elements of his calling—patients, students, nurses, colleagues, and though his manner was reserved and undemonstrative, it did not long conceal his warmth of feeling from those about him. His character and personality inspired respect, admiration and affection. His qualities and attributes and tastes were thoroughly human, but perfectly disciplined to serve useful ends.

In the leisure of advancing years, with undimmed faculties but failing physical powers, he turned again to intimacy with Nature, and to the company of favorite books. In 1915, two months before his death an honorary fellowship in the American College of Surgeons was conferred on him. Of this scene, Warren wrote: "And when at the recent convocation the honorary degree was conferred upon him, and I saw him for the last time, in the robe of the order, he seemed to me to have come into his own again. The sombre folds of the academic gown served as a fitting setting to the grave and intellectual features of the man, and while, during a pause in the proceedings arranged to allow him to retire, he passed slowly down the aisle, leaning upon a proffered arm, his assembled colleagues rose as one man to do him honor as a recognized leader in their chosen profession."

DAVID CHEEVER.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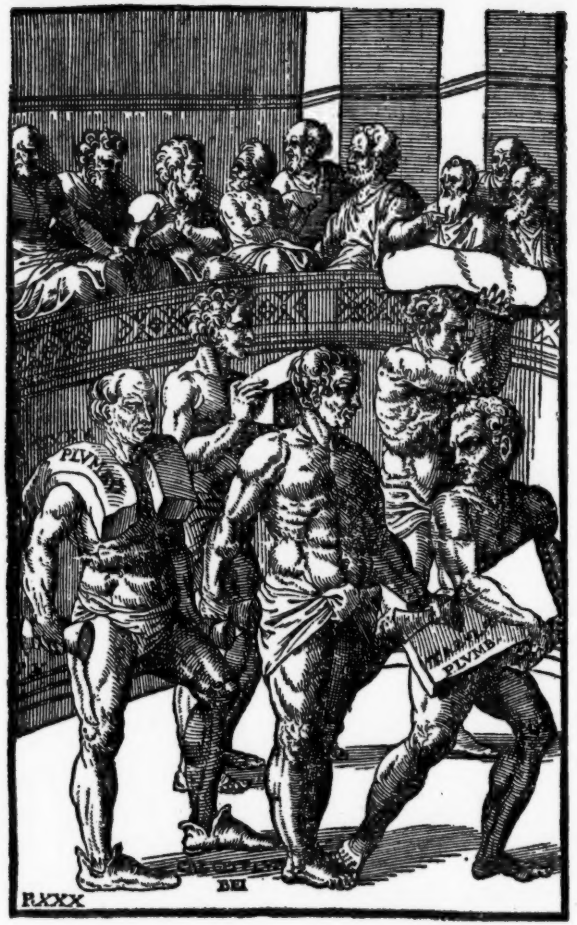
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THE SURGEON'S LIBRARY

OLD MASTERPIECES IN SURGERY

By ALFRED BROWN, M.D., F.A.C.S., Omaha, Nebraska

CONCERNING THE GYMNASTIC ART BY HIERONYMUS MERCURIALIS

FROM earliest times history affords many examples of the use of exercises both in military and civil life. The ancient athletic games of Greece, the gladiatorial and other contests of ancient Rome, and the evidences of contests of athletic prowess among the eastern peoples all bear witness that from the Dawn of Civilization the training of the human body to withstand the physical stress of life had its place. That these exercises were graduated and carried on according to an orderly scheme with this idea in view is not too well recognized. Likewise the baths of ancient Greece and Rome are commonly looked upon as places of sybaritic enjoyment rather than as institutions of medical and surgical balneotherapy; in fact it has been of only recent date that the true value and place of physio- and balneotherapy have been generally recognized in surgical therapeusis.

Hieronymus Mercurialis made one of the first attempts to bring the efficacy of gymnastic procedures as curative measures before his profession in the sixteenth century. Mercurialis was not only a famous surgeon, holding in succession the professorial chairs at Padua and Bologna, but also was one of the most learned men of his century and interested largely in world affairs. At one period of his life he spent 7 years in the home of Cardinal Alessandro Farnese and employed much of this time in the study of the manners and customs of ancient peoples and later adapted the knowledge thus gained to the medical and surgical practices of his period.

In 1569 when 39 years of age he published the first edition of his *De Arte Gymnastica* and in 1573 the second edition appeared. In this year he was called in consultation to Vienna by the Emperor Maximilian II and as a natural consequence, the volume is dedicated to him. The title page reads: "The Six Books of Hieronymus Mercurialis Concerning The Gymnastic Art. In Which Are Diligently Explained the Kinds, Places, Manners, Forms and All Ancient Exercises and Also Whatever Pertains To The Motions of the Human Body. Second Edition Enlarged and Embellished with Many Illustrations. A work not only medical but also very useful to all desirous of learning of ancient affairs and especially of the conservation of health, (dedicated) to Maximilian II Emperor. In Venice at the house of Guinta, 1573."

Following the usual dedication and laudatory poems of the writer's friends comes a list of authors whose works Mercurialis has consulted. The first book is largely historical and explanatory. He begins with a sketch of the principles of medicine and lays down the dictum that there are two parts of medicine; the one curative, the other conservative. Gymnasia have to do with the latter part and he passes on to a description of the ancient gymnasia and baths, the plans of which are illustrated as well as described. Finally he ends this book with his division of ancient gymnastics into three types, the gymnastics of war, the gymnastics of medicine, and the gymnastics of athletics, and it is interesting to note that he praises medical gymnastics as legitimate and condemns those of athletics as faulty or bad (*vitiosa seu athletica*). In the second book Mercurialis discusses the various types. He first tells what exercise is and how it differs from labor and simple motion. He describes exercises such as dancing and passing a ball from hand to hand and goes on to the more strenuous exercises such as football, wrestling, boxing, and the athletic feats with the discus, etc. In the third book he considers the more truly medical principles of exercise—the benefits of walking; proper carriage of the body, the exercise of restraint, singing and laughing, swinging, riding and many other forms—not the least important of which is the discussion of the necessity for exercise for the bedridden or those who for other reasons are unable to work and get normal exercise in this way. In this class he includes those who must of necessity lead a sedentary life, mentioning in particular emperors, kings, and princes. He speaks of the benefits of fishing, sailing, swimming, and hunting.

The fourth book is in great part polemic and endeavors to confute the arguments of those on the one hand who condemn exercise as unnecessary in the healthy and on the other those who declare that exercise is necessary and beneficial to all, irrespective of their physical condition. These two classes out of the way, he discusses the proper exercises for various types of persons: the well and the sick; the young and the old; and in the fifth and sixth books develops this theme in detail, prescribing the types of exercise indicated for the different conditions commonly encountered.

The work, even at the present day, is a mine of information, both historically for its description of the ancient gymnasia and baths; and its sound common sense advice as to the care of the body through properly guided exercise.

REVIEWS OF NEW BOOKS

I BELIEVE it was Murphy who said that the story of appendicitis should be rewritten each ten years. When one studies the mortality statistics of appendicitis of hospitals the country over the statement of Murphy can be amply justified as the mortality rate of this disease is entirely too high. Many competent surgeons have a higher mortality rate for appendicitis than with gall-bladder or conservative stomach surgery. The reason is not alone a lack of skill in operative surgery or surgical judgment but the cases come to the surgeon too late—many times with a ruptured appendix with abscess or beginning diffuse peritonitis. The differential diagnosis in many instances in not by any means simple and clear cut. One has only to remember the cases of early central pneumonia or acute upper respiratory infections in children that give almost typical symptoms of appendicitis and in contrast the gangrenous appendix that gives virtually none of the classic symptoms of acute appendicitis. Relatively speaking no acute disease within the abdomen in its early stages is so frequently mistaken.

The answer is, the story must be rewritten and it has been rewritten by Royster.[1] In his recent excellent monograph the author brings to the profession in a most lucid manner the complete story of appendicitis both acute and chronic. The author attempts to give little if anything new but relates in an orderly fashion, all the work that has been done the world over. One must be pardoned for enthusiasm shown for his excellent description of the differential diagnosis. Here lies the crux of the situation and he has covered it in a most instructive and complete manner. The chapter on complications is complete, bringing to the reader's attention such conditions as liver infections, pylephlebitis, subdiaphragmatic abscess, intestinal obstruction and the like.

Every practitioner of medicine should profit by reading this monograph; in fact the general practitioner will receive from it the greatest benefit, as he is the man who sees 95 per cent of the early cases of acute appendicitis and must recognize them in order that prompt life saving measures may be adopted. It is pleasing to note his criticism of the practitioner who tends to wait and trust, fearing to advise surgery. How often this procrastination has led to disaster.

The author incorporates an accurate description of the Ochsner treatment, its indications and method. It is common knowledge that there exists, one might say, an almost universal misunderstanding as to what Ochsner meant when he advocated this method in 1902 and again in 1921. There is no question but that a wide dissemination of this fact alone will save many lives throughout the world.

What is known today of the appendix, its diseases and accompanying pathology and complications, and of proper treatment is clearly and concisely set forth in this most excellent monograph.

JOHN A. WOLFER.

IN this little work[2] on the diseases of newborn infants Burnet endeavors to save the student the hopeless task of gleaning a knowledge of the subject from the mass of literature that has accumulated. In this the author has been fairly successful. Perhaps he has devoted relatively too much space to the less common diseases, but all in all the subjects are presented clearly and concisely, and in a most readable manner.

The discussion of circumcision is superb. Says the author: "As a routine measure it cannot be too strongly condemned. The argument that it conduces to cleanliness and mitigates venereal infection is not a valid one. A freely movable prepuce is perfectly hygienic, and is more ideal and more to be desired than the condition in which the glans is left entirely exposed. The operation is not to be undertaken without due consideration of the risks."

PALMER FINDLEY.

IN this volume on *Birth Injuries of the Central Nervous System*,[3] one finds a large number of facts which in many instances directly controvert much of the vague and loose talk which has been handed down in much the same fashion as folk lore. It is rather enlightening to note that these authors, primarily interested in neurology, are invading the obstetrician's field of clinical investigation and come to his defense. A great part of their work was made harder by the incompletely recorded histories and physical examinations of these patients. So it must be with a sense of obligation that the obstetrician reads that "the great mass of infantile palsies can no longer be lightly attributed to faulty obstetrical procedures." An excellent bibliography adds to the attractiveness of this monograph, which represents a thorough study of a rather difficult subject matter.

LOYAL DAVIS.

[1] SURGICAL MONOGRAPHS. Under the editorial supervision of Dean Lewis, A.B., M.D., Eugene H. Pool, A.B., M.D., and Arthur W. Elting, A.B., M.D. APPENDICITIS. By Hubert Ashley Royster, A.B., M.D. New York and London: D. Appleton and Company, 1927.

[2] DISEASES OF THE NEWBORN; A TEXTBOOK FOR STUDENTS AND PRACTITIONERS. By James Burnet, M.A., M.D., F.R.C.P. (Edin.). New York: Oxford University Press, 1927.

[3] MEDICINE MONOGRAPHS, Vol. xi. Birth Injuries of the Central Nervous System. Part I—Cerebral Birth Injuries, by Frank R. Ford; Part II—Cord Birth Injuries, by Bronson Crothers and Marian C. Putnam. Baltimore: The Williams and Wilkins Company, 1927.

AMERICAN COLLEGE OF SURGEONS

THE PARASITIC ORIGIN OF MAN[1]

The Bionomics of Animal Reproduction in Relation to Tumors and Cancers

By Sir JOHN BLAND-SUTTON, Bt., F.A.C.S., London

IT is a privilege to deliver this Memorial Oration. I accepted the invitation because I knew Doctor Murphy and appreciated his zeal for Surgery and the ability with which he practiced the art. His enthusiasm as a teacher and as an exponent of surgical pathology is well known and universally recognized. I met him for the first time in London in 1895 at a meeting of the British Medical Association. I was secretary to the Surgical Section and won his heart by finding a cadaver on which he could demonstrate, to a group of surgeons, his method of making an intestinal anastomosis with the aid of his ingenious button. I was delighted with his technical skill; our friendship was sealed with the button, and this metallic device served to fix Murphy's memory in the minds of surgeons throughout the world. He was something more than a mere technician. His deep interest in surgical pathology is manifest throughout his famous *Clinics*. Knowing his interest in the surgery of tumors the oration today is concerned with an aspect of the tumor question which I feel sure would have interested him.

The theory of the origin of man from lower animals finds its surest foundation in embryology, and some remarkable observations and discoveries relating to tumors are concerned with this branch of biology.

The greatest discovery man ever made about himself was when von Baer in 1827 discovered, with the aid of a microscope, the human ovum. When ripe the ovum is a spherical cell just visible as a mere speck to the naked eye. The riddle of animal reproduction remained unsolved until Koelliker recognized the importance of the minute flagellate cells called spermatozoa. These remarkable cells were discovered by Hamm, a pupil of Leeuwenhoek in 1677. They resemble protozoa, and were called spermatozoa. For many years they were regarded as parasites of semen until Wagner and Koelliker in 1844 proved them to be histological elements of the testis. No one has witnessed the union of a spermatozoon with a human ovum; it is a matter of inference from observations made on the eggs of starfishes and amphibians. In such creatures, ova and spermatozoa mingle in the water and come into vital collision, and the act of fertilization can be seen under conditions permitting accurate observation. Biologists who have studied the process of fertilization notice that when mature ova are brought into the vicinity of sperm, the spermatozoa, influenced by their presence, make energetic efforts to reach them.

THE AQUATIC ORIGIN OF MAN

There is good evidence that man is derived from aquatic ancestors and the stages he passes through before becoming fit to be born indicate that the fetus in the womb lives as an aquatic parasite within its mother. When an ovum enters the uterus, the overgrown uterine decidua on which it rests, secretes a fluid for its nourishment. This fluid is aptly named by Teacher, in a recent admirable research, uterine milk. The ovum can flourish in this medium about 10 days. If the environment be favorable fertilization is effected by an active spermatozoon. The ovum, in consequence of its union with the head of the spermatozoon, becomes an oosperm, or zygote, and is quickly invested with delicate membranes. Of these, the outer, known as the chorion, quickly becomes shaggy with protoplasmic bodies called chorionic villi. These villi erode the adjacent decidua and firmly embed the oosperm; they are, in due course, converted into a placenta—the respiratory organ of the fetus. Fluid accumulates in the amnionic cavity and in due course the embryo disports itself actively as an aquatic creature in its own amnionic pool.[2] In the early

[2] The source of the amnionic fluid has puzzled embryologists. From a long and careful study of congenital defects affecting the urinary organs, I have satisfied myself that this fluid is mainly urine excreted by the fetus. Recently a surgeon related to me these facts:

A pregnant uterus was removed on account of serious complications, and at the moment the uterine cavity was opened and the fetus set free it was caught in the act of passing urine in a full stream. The fetus was in the fifth month of gestation.

[1] The John B. Murphy Oration in Surgery, presented at the Clinical Congress of the American College of Surgeons, Detroit, October 4-7, 1927.

stage its skin is covered by a single layer of cells. Later this becomes double and the superficial layer is known as the epitrichium. About the eighth month of intra-uterine life the epitrichium is cast off mixed with grease from the skin-glands and the delicate woolly hairs known as lanugo. This soapy stuff is the vernix caseosa so conspicuous on the skin of the newborn child. The epitrichium persists on aquatic creatures such as frogs and salamanders and protects their skin from maceration. When the human fetus, as an aquatic creature, disports itself in the amnionic hydrosphere the epitrichium and vernix caseosa protect it from maceration. Occasionally the epitrichium persists and the fetus dies; in such circumstances when discharged from the uterus it presents a weird appearance and is known as the harlequin fetus.

The human fetus is an aquatic mammal, its blood being oxygenated by its mother's blood by means of the placenta; at birth it is expelled from the uterus, discards the placenta, and becomes a lung-breathing creature.

Few things made a deeper impression on my mind than when, as a child, I realized that the tadpoles which emerged from the frog-spawn in the ditch bordering my playground turned into frogs which jumped among the long grass in the paddock. This was my earliest lesson in embryology. When I became absorbed in anatomy and morphology, the changes in the branchial bars, as the aquatic tadpole transformed into an air-breathing amphibian, became more interesting, especially on learning that in man their chief representatives are the delicate chain of ossicles—malleus, incus, and stapes—in the tympanic cavity. It requires little imagination to realize that "the first landmark in the ascent of man was when the frog first found a voice and left the water," but, true to its origin, *the frog must return to the water to spawn.*

Recently Leathes, in an admirable summary concludes that life consists in organic compounds continually reforming themselves and that the sea is the native environment originally of all forms of life.[1] The importance of water is emphasized by the knowledge that the greater part of our bodies (two-thirds) is water.

CHORIONIC VILLI

An ovum is propelled through the fallopian tube in about 3 days. Normally the life of the ovum is spent in the cavity of the uterus, a suitable place for its reception and nourishment. When an ovum is attacked by a spermatozoon it is changed from a placid into an active cell, which burrows into the endometrium like a vigorous parasite. The initial effect of this invasion is the immediate arrest of menstruation; no one has suggested an explanation of this remarkable effect.

Thirty or forty days after fertilization the oösperm has undergone some remarkable changes. It has increased enormously and become a cyst with a thin, delicate, transparent wall containing a visible embryo, and its outer wall is shaggy with delicate tufts known as chorionic villi. In the early stages the villi are devoid of blood vessels; they consist of an axis of delicate connective tissue supporting cells rich in protoplasm. These cells are peculiar in character and with the aid of a microscope are easily recognized by competent histologists. The chorionic villi are the chief cellular elements of the placenta. The cellular caps of the villi possess erosive powers which enable them to erode maternal tissues and blood vessels. Chorionic villi have become the subject of intense study. A century ago it was discovered that the curious product of conception known as the grape-mole (Traubenmole) is due to changes in the chorionic villi. Examples are preserved in most pathological museums. Scientific knowledge percolates slowly and this disease remained a curiosity until Saenger and Pfeiffer, in 1889 independently described a malignant type of uterine tumor, peculiar in structure which attacked parturient women. Subsequent investigations by many observers proved that such perversion is associated with the chorionic villi. It is now well known as chorionic cancer, and its prime features are an exaggeration of the eroding properties of the villi; they penetrate the walls of the uterus and may invade the peritoneal cavity. When they erode blood vessels, fragments of the villi are deported by the blood stream to the heart, lungs, bones, viscera, and brain, giving origin to secondary deposits and sometimes the patient succumbs with astonishing speed. Examples of the spontaneous disappearance of chorionic cancer have been reported. This betrays its alliance with the placenta which is a temporary organ.

The natural history of chorionic villi illustrates in a remarkable way the distinguishing features of the cancer cell: for example, its power of independent growth, erosiveness, and vitality which enable it to undergo dispersion and establish itself in parts of the body remote from its origin.

The natural history of the placenta is astonishing, but facts have been gradually accumulating which increase our astonishment.

The placenta dominates the life of the fetus. The termination of its intra-uterine life coincides

[1] Lancet, 1926, xi, 265.

with that of the placenta, and at the end of 280 days, if the child is not expelled, the fetal circulation stops, the babe dies, the placenta dies, and is slowly absorbed. It is significant that a ripe placenta never becomes malignant. The villi—the immature elements—are the source of chorionic cancer.

The pathologist's interest does not end here.

OVARIAN DERMOIDS—MISDIRECTED EMBRYOLOGIC ENERGY

When the wonderful effects which follow the vital collision of a spermatozoon with an ovum were unravelled by embryologists, the spermatozoon seemed to be the essential factor in initiating developmental changes in the ovum. There are reasons for believing that this privilege is not peculiar to the tailed-cell.

Ovarian dermoids are familiar to surgeons today but fifty years ago they were regarded as curious tumors found after death.

With the establishment of ovariotomy they were found to be common tumors, but though common they are very remarkable. Nearly all organs normal to a fetus have been found in them, except the reproductive gonads: skin with all its special elements, lanugo, hair, glands, and nails; brain tissue, choroid plexus, and spinal cord; eyes, teeth, cartilage and bone; trachea with mucous membrane, and thyroid gland; intestine and liver. The essential element is a skin-covered lump which often resembles a mammary gland; sometimes with a nipple surrounded with an areola. Sometimes a rudely shaped head and a stunted limb. These ill-formed lumps known as embryomata, represent an ovum which has developed without the stimulus of a spermatozoon.

While pathologists were puzzled by such occurrences, Loeb induced the eggs of starfishes to segment by adding soda-water to the sea-water of an aquarium—shock fertilization. Later Batallion induced complete embryogenesis in the eggs of grass frogs by gently puncturing them with extremely thin metal or glass stylets dipped in frog's blood. It is now a common experiment in biological laboratories in spring-time to produce "fatherless-frogs." These experiments have an important bearing on the origin of ovarian dermoids and support the opinion that they are due to the activity of ova.

The nature of ovarian dermoids has engrossed my attention for nearly 50 years. These tumors in some instances weigh nearly 50 pounds. Gradually I realized that the mass of grumous stuff which often forms the greater part of the tumor is excrementitious. The embryoma, the essential part of the tumor, is skin-covered and the skin sheds epidermis, lanugo, hair, sebum, etc., hour by hour, day by day, month by month, and year by year, until the accumulated rubbish make the tumor conspicuous.

I have often wondered at the frequent presence of skin, hair, and teeth in dermoids and pondered on the absence of intestine. How blind have I been!

A peculiarity of the cubical cells lining the gastro-intestinal track is the large amount of colloid material which forms in them under pathological conditions. The biggest tumors which form in women are ovarian dermoids. Many years ago I urged that the membrane lining the honeycomb chambers of these huge cystic masses was mucous membrane. Gradually I became convinced that they are embryomata in which gastro-intestinal epithelium is dominant.

In ovarian dermoids skin prevails and the accumulated rubbish—sebum, epidermis, lanugo, and teeth—is detritus from the skin. This rubbish is the equivalent of the vernix caseosa of the uterine fetus.

In ovarian colloid cysts mucous membrane prevails. The accumulated stuff is pseudomucin furnished by the gastro-intestinal epithelium of the embryoma.

Between the extreme types there is every gradation of misdirected embryologic energy. These tumors arise in ova which develop independently of spermatozoa. When an embryoma is well organized the character of the dermoid is easily recognized and it is non-malignant. They endanger life by their bulk and septic infection to which they are liable.

Although I have spent much time in studying the minute structure of ovarian dermoids I have not detected in them any evidence of testicular tissue or chorionic villi. In 1902 Schlangenhaufer discovered in a testicular dermoid, tissue identical with chorionic villi. His observations have been confirmed by other histologists. In some instances the tissues closely resemble that of the grape-mole.

It is noteworthy that examples of malignant testicular dermoids, in which chorionic elements were detected, have been associated with enlargement of the mammary glands. After ablation of the affected testis, the mammary disturbance subsided.

It is worth mention that among the peculiar tumors which occur in the ovaries of adult women, known as papillomatous cysts, there is a variety in which the microscopic structure is like that of chorionic cancer. This variety is malignant and is disseminated by the blood stream. The second-

ary tumors erode bone with facility. In one example under my observation the secondary growths were in the superior mediastinum, and bud-like processes eroded the manubrium of the sternum and appeared as currant-like nodules under the skin.

Papillomatous cysts of the ovaries are, as a rule, bilateral and occur in women between the twenty-fifth and fiftieth years of life.

It is difficult to escape from this conclusion: *Pregnancy is an epitome of a parasite infection.*

The fetus may be regarded as a tumor growing within its mother, the consequence of an infection by a parasite—the spermatozoon. It is a strange eventful history. Copulation is the method of infection by which flagellate protozoa—spermatozoa—introduced into the female attack ripe ova in the uterine, or the tubal passage and convert one or more into oosperms (zygotes). The oosperm embeds itself vigorously in the ripe decidua. The first effects of the infection are a local reaction—the arrest of menstruation, and a constitutional response expressed by mammary activity and the secretion of milk; and usually pigmentation of the skin localized to certain definite situations. The uterus, in a marvellous manner, adjusts itself to the growth of the fetal tumor and at the end of 280 days, the death of the placenta coincides with labor and the expulsion of the child and its membranes. The fetus becomes an air-breathing mammal, leads an independent life, becomes in due course mature, and seeks opportunities for reproducing its kind.

PARTURITION

Childbirth is a natural operation and like a surgical operation has its risks and sequences. Of these the two most important are sepsis and cancer, one is immediate and the other deferred.

In spite of the brilliant results which ensued on the conquest of sepsis and the treatment of wounds, childbed fever persists. It is true that endemic puerperal fever disappeared when Listerian principles were applied, but the sporadic form persists and will persist until parturition is conducted on the same strict methods as surgical operations. Take for example cesarean section. In 1860 this ancient operation had an enormous mortality. Today it is safer than normal delivery at term, since surgeons have adopted aseptic methods—boiling instruments and ligature material—and especially wearing sterilized rubber-gloves when conducting labor.

To reduce the risks of parturition to the level of a surgical operation, parturient women should be treated on the same lines as a perspective surgical patient. *She should not be ashamed to wash the gate-of-birth with the same diligence and care as she washes her face.* Such a toilet is of the utmost value as a protection against postpartum sepsis.

Chronic ulcerating septic fissures in the walls of the birth-canal are the lurking places of pathogenic germs, and potential sources of uterine infection and cancer.

Science hath given a new commandment to doctors and midwives:

> Thou shalt wear sterilized rubber-gloves in taking a labor; for the law will not hold him guiltless that taketh a labor with bare hands and the lying-in woman develops childbed fever.

We flounder in speculation concerning the causes of tumors and cancers, as much as our predecessors floundered in ignorance of the factors concerned in animal reproduction. The microscope enabled us to recognize mammalian ova and spermatozoa and work out their intimate relations.

> Verily the tale of animal reproduction is the most wonderful history in the world; it is an epitome of Man's descent from protozoa.

THE RESPONSIBILITIES OF THE SURGEON TO THE PUBLIC[1]

By GEORGE DAVID STEWART, M.D., F.A.C.S., New York

THE discovery by Pasteur of the causes of many diseases and of most of the plagues that have afflicted mankind, changed abruptly and forever the responsibilities of the medical profession to the patient individually and to the patient in mass—the public.

Under these changed conditions the profession in America has striven indefatigably and altruistically to fulfill their responsibilities but the opinion will be here expressed that much of this effort is wasted, partly on account of the great number of agencies engaged in giving medical education to the public and the overlapping of their activities but also and chiefly because a large portion of the public cannot understand much of the information offered to them in this way and never will be able to understand it. Further, it is believed that the best way of teaching the public is to bring an educated and sincere profession into contact with a sanely intelligent citizenry.

There are in America between 30 and 40 societies, national in scope, engaged in presenting to the public a certain amount of information regarding a single disease in which they are individually interested.

In addition, every large city and most of the small ones have, beside their hospitals, municipal and private, their dispensaries and public health departments, many other medical or allied activities covering geographically the block, the parish, or the town. Some of these function independently, many of them overlap to greater or lesser extent, while some are in mortal conflict: thus it is not physically possible for prenatal clinics and birth control to flourish in the same soil. New York has besides its hospitals and dispensaries more than 30 local or city organizations and Chicago is blessed, at least possessed, with as many, perhaps more.

Recognizing that from the multiplicity of these organizations and the variety of their interests there were certain to result overlapping and confusion, the Council on Health and Public Instruction of the American Medical Association was selected by the societies to act as the single spokesman for the group, that the speaking might be with authority and not a confusion of tongues.

The machinery set up by this council established a *press bureau* which sent clippings and other information on medical matters suitable for printing with the *imprimatur* of the council to 5000 newspapers (this was about 1913). There was also established a lecture bureau and medical lectures were furnished free on request of local societies. A library of lantern slides and other illustrations, radio talks, and various other services and equipment could be had on demand.

The work done by the profession through the Council, later changed into the Bureau, has been enormous and of value no doubt but it has not met with complete success. At least, it has not succeeded in becoming the universal spokesman, for, one of the societies referred to has recently obtained a million dollars in order to spread information in its own way about the disease in which it is interested; and another is spending several millions a year in similar propaganda. There can be no criticism of the motives which inspire these efforts, but surely it is a poor method of instruction that attempts to make specialists of the laity and an expensive method that can teach only one disease at a time.

The International Health Board reports 341 county health units in operation in 34 states for the year 1926. These county units carried to the poor and to those remote from large centers the advantages of up-to-date methods in medicine. The profession here bore a relation to the public similar to that of the family doctor. Of organizations like these that teach medicine to the public but only as incidental to the treatment of the public there can be no criticism. Lord Salisbury said a missionary must soon be followed by a gunboat but he never meant this to apply to medical missionaries.

THE EDUCATION OF THE LAITY

The public may be divided into four groups as far as their lay education is concerned. A large group receives only the so-called elementary education which is compulsory, ends at 14 years of age, and is now supplemented in many localities by part time continuing schools which carry the student approximately to his seventeenth year. A second group, smaller in number, receives the secondary education covered by the high school. To a third group less in number than the preceding but still very large, for America has more colleges and more college graduates than any other country in the world, is given the so-called

[1] Inaugural address, the Clinical Congress of the American College of Surgeons, Detroit, October 3, 1927.

higher education. America has, too, a relatively large number of illiterates making a fourth group.

Reading is not education and the largest group, the first, will depend largely on the public press for its knowledge of things medical, excepting, of course, those individuals who have a trusted family doctor. Many reputable newspapers and magazines exclude from their columns all medical information of doubtful authority and all advertisements except those strictly ethical. Further, many publications have reputable doctors attached to their editorial forces. In spite of this, much that is sensational and misleading finds its way into print.

The charlatan and quack have ready access to this sort of publicity and, conscious of the fact that the public cannot discriminate, are perfectly willing to enter into controversies which serve to advertise their wares while it utterly fails to classify them.

This, in passing, is an argument against the doctor's advertising himself, recently recommended by a well known writer in a reputable publication. The pretender in medicine or a sincere adherent of one of the cults has the same opportunity of advertising: there is no tribunal to decide between him and the reputable profession except public opinion and public opinion is not technically well enough informed to make such a decision. The party willing to make the most extravagant claims, promising the most to suffering, often bewildered, humanity, has in such a contest an even chance of winning.

Another grouping of society not based on the lay education of the public but on the amount and kind of medical information it wants may be made. Old age is a condition youth seldom feels called on to contemplate. Similarly, health, arrogant and young, or perhaps careless and old, is rarely interested in discussions concerning disease. So long as the machine goes on without friction there is no, or only a mild, interest in the machine, but let the evil days fall, the man of intelligence seeks the aid of the best doctor he has heard of through his friends; the other, and he may even be one who has received the higher education, flees to the mountains of promise with no rock of achievement beneath.

Beside those who are incapable of receiving and those who do not want medical information there is another large section of the community which wishes to be fooled. Mankind has always been looking for some means of cheating the jinx. For these, medicine can possess potency only if its methods are mystical and its terminology turbid. Teach that attenuation increases power, it will be accepted eagerly as long as the reasons are not given or if given are not reasonable. Their credulity may be drawn upon without ever stopping at the boundaries of knowledge and there is no limit to the vasts of ignorance.

In that stage of man's spiritual development when he regarded each object as possessed by an *animus* usually hostile, it became necessary to convert it to friendliness. Soon there arose among the sons of men, bright shining spirits who for a consideration would undertake these conversions. That these shining ones were the brightest of their tribe and that to them fell these tasks with their remuneration, is not to be wondered at or made the subject of crabbed cavilling. This was a stage perhaps as necessary in man's progress as was the polytheism of later and admittedly more civilized times. There are still many who prefer their medicine at the hands of the Shaman, who expect tumors to be removed by salves that have a *soopling* action, stones in the gall or urinary bladder to be dissolved by waters from Arbana and Pharpar and, from monkeys, not merely rejuvenation but resurrection.

To those best educated, as education is commonly qualified, the doctrines and tenets of the cults often make appeal when couched in terms unintelligible to most. Who knows that a consciousness of calm may not come to comfort the harassed soul and the suffering body through channels unrecognizable by what we commonly call intellect? An understanding doctor meets such cases with sympathy, not intolerance. The Romans believed in bodily health as a form of religion, holding that spiritual good might enter through the subtle gateways of the body. Every doctor knows that bodily functions are profoundly influenced through the far more delicately subtle currents of the mind.

Among educators today there is a growing conviction that education should never end but should go on all through life. This is an acknowledgment of the fact that there are certain subjects concerned closely with the texture and art of living that cannot be understood until experience with life has touched them and made their import and meaning clear. Aristotle believed that political science was not suitable for and could not be taught to the young. Newman said, "Read Horace if you will but don't expect to understand him until after you are 40 years of age."

In Denmark this continuing education is met by the special high schools which are open to everyone over 18 years of age. These, originally established to keep alive the language and traditions of the race threatened by foreign aggression

and domination, have been continued for the betterment of the people and because of the profound influence they have exercised on the moral, spiritual, and even economical welfare of the Danish race. An agricultural people largely, it might be supposed that the curricula of their schools would be in some measure at least concerned with farming. Such is not the case; instead literature, history, and art are taught. By means of the first, they can count the heart throbs of the world, through the second they learn what institutions man has founded to help him in his upward climb. From these studies, held at convenient seasons, they go back, not away from, their farms, conscious of the dignity of labor and contented with their lot.

It is this kind of broadening education rather than technical knowledge of medicine that is needed in America today.

The medical profession long ago recognized the need for a continuing education, a necessity sensed by almost no other profession, in similar degree certainly by none. Academies of medicine, medical societies, clinical societies, and assemblies everywhere bear witness to the desire of the medical profession to continue to learn all through life. Perhaps medicine is more dynamic than the other professions but if this implies a fault it contains a virtue, for so is life dynamic and there can be neither life nor world without tradition or without change.

STANDING

In no profession are the standards of education so high as in medicine, and this is due to efforts of the universities and the state medical licensing boards but mostly to the doctors themselves as represented by the American Medical Association. At the present time 95 per cent have a good general as well as a good professional training, and according to the Commission on Medical Education in its preliminary report of January, 1927, for the first time the standards of medical education in America bear favorable comparison with those of other countries.

A high standard of education, however, does not connote a high standard of character or of ideals. The age is commercial and the public is demanding that its higher education be practical in character. A recent writer insists that the male students in the colleges not only do not ask for any cultural or liberal training but that they do not even know the meaning of these terms. Medical education, particularly premedical is, of course, dependent on general education and takes from it both color and tone.

If this is true and if the profession wants the confidence of the public, it must be understood that it cannot be had on a commercial basis but only on that of the soundest and highest ideals.

The French have long recognized in their system of education that the cardinal virtues of honesty and sobriety are taught by example and not by precept. It is obvious that to have advised the "artful dodger" that honesty is the best policy would not have succeeded; but the example of an honest father or mother would have silently and surely accomplished that end.

While medical colleges then have scanned the antecedents as closely as they have the intellectual equipment of candidates for admission they have made no effort to teach in the school any of the cultural or humane or liberal subjects. It is, of course, impossible to lecture ethics into students at any age; particularly is this true of medical students.

Still there could be no harm in injecting into the curricula, overcrowded as it is, a short course, e.g., on the history of medicine on great epochs and particularly on great men. Pasteur advised young men to reverence their masters and himself gave an example by strewing flowers on the grave of one of his beloved teachers every year on the anniversary of that teacher's death.

To learn with what difficulty new ideas are born and with what tenacity worn-out, discarded, useless views cling to life is in itself an education in science and humility. At the present moment the colleges have before them the task of clearing out of the attic of the curriculum junk that has been collecting for years. Further, because of the rapidity of discovery, it will be necessary to recognize that one small head can never carry all there is to know and to make selections of the material most in demand and most useful. It was Herbert Spencer who pointed out that it might be useful once in a life time while arranging a railway journey to know the names of the cities of England, their distances apart and by what railways they might be reached but that compared to other information this was of little relative value and might be looked up with ease on the few occasions required.

The general reaction to the efforts of the medical profession to educate the public and to improve and elevate the standards of the profession is very interesting and tells an eloquent story: of increasing (legal) state recognition of irregular practitioners, of wider acceptance of many forms of medical service based on false interpretations of disease, of false theories of diagnoses and treatment, of low educational standards, and of the

absence of ideals. Under these conditions irregular practitioners according to the report of the Commission on Medical Education have increased 200 per cent in the last 15 years.

There is no question, of course, that certain broad facts may be taught, indeed must be taught to the public, e.g., that a lump in the breast of a woman should be investigated, that an ulcer anywhere should not be suffered to long continue; but there is no formidable array of such facts and the contention is that giving the public information through lectures and newspaper articles often leads them to believe that they themselves are versed in medicine or sends them to worship at the shrine of strange gods.

Let it be again emphasized that a society which teaches the public while treating them assumes the position and relationship of the family doctor.

On the other hand few of the clientele of the altruistic general practitioner ever desert him for newer gods. Aware of his keen and sympathetic interest, of the fact that he knows their systems both physical and moral, they care little how much they understand of medicine but greatly how well they are understood.

It is, perhaps, true that the general practitioner is disappearing. But 90 per cent of the demands on the practitioner (again quoting the report of the Commission on Medical Education) are for illnesses that cannot be treated on a community basis; that is, for problems of the individual. The general practitioner will re-appear. He has been coming and going through the centuries.

When man is suffering, perhaps fronting the great darkness, there is in his heart a cry for understanding sympathy. Science changes, but the emotions of the human heart are constant, and men and women still weep over the tragedies of Euripides but bear with fortitude the prediction of science that they will be superseded by a race of supermen.

AGENTS MODIFYING THE GERM PLASM[1]

By CLARENCE COOK LITTLE, A.B., S.D., LL.D., Ann Arbor

FOR centuries the attitude of the medical profession toward heredity has been a matter of great interest and of many-hued changes.

As a general thing the physician or surgeon has been brought forcibly and repeatedly in contact with the striking phenomena of such processes as infection, contagion, immunity, and malnutrition. He has therefore been led to express a keen and constructive interest in these things and has aided notably in advancing human knowledge of the fundamental principles which they involve.

During the same period there was, until 1900, no adequate laboratory method of testing the strength or nature of the process of inheritance in any given case.

In 1900, however, Mendel's Law was rediscovered. At once, there was a great increase in the amount and value of genetic research. In the 27 years that have elapsed since then experimental genetics has advanced to a point where our knowledge of the physical basis of heredity is, if anything, more extensive than are our facts on many of the processes with which medical men have long been familiar, and to which I have just referred.

So rapid has been this progress that many experimental geneticists, bewildered by wealth of material and the great number of recorded results, have been forced to specialize to some extent. This has resulted in the development of more or less isolated groups, all recognizing the same fundamental principles but so far along the road of fascination for their own material that they have lost a sense of proportion in interpreting their results.

An excellent example of what I mean is to be found in Slyes' work on the genetics of cancer. Having for almost 15 years been *in* a pathological and *out* of a genetic laboratory, she has collected with great patience an enormous number of pedigrees of families of mice in which neoplasms may or may not occur, for the *genetic interpretation* of which her published works show repeatedly and consistently that she is unfitted. Her interpretations have, however, been swallowed whole by editors of medical journals and others of the profession whose direct contact with genetic laboratories may in some cases be even more antiquated than is her own. As a result there is bound at some time to be disillusionment, disappointment, and, in all probability, discredit of genetic methods, entirely undeserved by those methods which are in no way to blame.

It seems to me that geneticists are largely at fault for the general situation that has arisen and that they should make every effort to discuss with medical men all matters of general and mutual interest, as early and as frequently as may be possible.

It is chiefly for this reason that I venture today to bring up the question of the germ plasm and the responsibility of the medical profession in using agents which may be able to modify the hereditary process in man.

In order to present the matter briefly, I shall try to proceed from certain broad generalizations to more definite and concrete applications of genetic research to the problem of radiotherapy.

LABORATORY STUDIES IN GENETICS ARE A SAFE APPROACH TO HUMAN HEREDITY

a. *The nature of present records.* Two methods of collecting records on the process of heredity in man are at present employed. The commoner of the two may be described as *indirect.* In this case the investigator consults with members of a given family concerning the characteristics both physical and mental of other members of that family and records their opinions. It can easily be seen that this procedure introduces grave errors. The opinion of different individuals concerning any one member of the family will vary as will also the opinion given by one individual concerning various members of the family. This method, however, has given rise to most of the pedigrees and family histories which are published by students of human heredity. Not only is it used by the individual investigators but it forms a large part of the recorded cases on file at such centers of scientific research as the Eugenics Record Office of the Carnegie Institute of Washington.

The second method which may be described as *direct* depends upon records of hospital cases and clinical observations. These records are usually imperfect in that they fail to ascertain by thorough examination the conditions found in living relatives of the individuals under observation. Much amplification is then necessary if records of this type are to have any value. Since the average space between human generations will be in the neighborhood of 25 or 30 years it is quite evident

[1] Fellowship address, Convocation, American College of Surgeons, October 7, 1927.

that records would have to be kept in a consistent manner for a far longer period than has up to the present time elapsed since the establishment of adequate systems of individual record. A marked exception to the usual type of inadequate records is found in the case of the Institute for Biological Research at Johns Hopkins University. There, every effort is being made to bring under direct observation all living relatives of any individual who serves as the starting point of an investigation. Since, as above stated, between 20 and 30 years must elapse before the complete life history of individuals of two generations can be obtained, by this method, we know that for purposes of present study even the best human records can not provide us with adequate information for a number of years.

b. *Records obtainable from laboratory animals.* In many ways the records which can be obtained from experiments conducted in the laboratory are far superior to those referred to above. The accuracy of the records themselves are far greater since the individual animal is under direct observation throughout its life history. The speed of successive generations even in slow breeding animals like dogs is greatly increased in comparison to human beings. In the case of such forms as mice, an average of between four and five generations a year means that results will be obtained about 120 times as fast as is the case with humans. Another factor of superiority possessed by laboratory forms is the great number of young which can be produced by a single pair of parents. This fact enables us to determine the extent of variation much more accurately than is possible in the extremely small families of human beings. A fourth factor of great importance is to be found in the controlled environment in which the animal is kept. By making the environmental factor essentially the same for all animals in a given experiment, many of the sources of non-genetic variation occurring in humans are eliminated.

c. *Comparable nature of germ plasm in man and other animals.* Detailed consideration of this fact will not be necessary since the essential similarity between the sex cells of man and other mammals and indeed between man and all other animals is recognized as a fundamental biological principle. It may be well, however, to point out very briefly certain of the facts.

Man in common with all other bi-sexual forms of animal life possesses a definite form which characterizes the gonads of each sex. The morphological differences are carried even farther than in the form of the gonads and are reflected in the actual shape of the male and female sex cells themselves. The generic resemblances between the human ova and ova of other animals, or between the human sperm and the male sex cells of other lower forms is obvious and essentially universal. Similarity of structure within the sex cell itself is also striking. The general relation between nucleus and cytoplasm in the sex cells of all animals is as nearly constant a phenomenon as it is possible to find in experimental biology.

Physiologically, also, the comparison is a very close one. Thus in the process of maturation, ovulation, and the various phenomena of the œstrus cycle, as well as in the process of fertilization itself, man and other mammals follow distinctly similar lines of physiological behavior. These facts clearly indicate that it is possible to draw a close analogy and in many cases a clear homology between man and lower forms.

EXPERIMENTAL EVIDENCE

a. *The direct effects of radio-active substances on sex cells.* One of the first and most striking series of experiments in this field was carried on by Oscar Hertwig and his children. Using as their material the sperm and eggs of frogs, toads, and other animals in which fertilization can be easily observed outside of the body, these investigators tested the effects of mesothorium and various radio-active salts on the process of fertilization and early embryological growth. They showed clearly that the sex cells were damaged by the treatment employed. A light dose of exposure to the radio-active agent allowed the sex cell, so exposed, to function, but produced as a result abnormal and monstrous embryos. A heavy dose given to the male sex cell allowed that cell to retain its motility and to initiate the process of fertilization without taking any part thereafter in determining the character of the offspring. *The fact that such exposure produced different degrees of injury, and that injured germ cells could function, is important and will be referred to again.*

The experience of early workers with X-rays and radium showed that complete sterilization was frequently observed where the radio-active substance was allowed direct access to the gonads. This effect has been observed repeatedly in the case of rats by Hooker and in mice by Bagg and the writer. Where sterilization is complete we may with fair certainty conclude that the sex cells have been killed or completely inactivated.

Of a somewhat similar nature, but of more importance to medical practitioners, is the fact that by a lighter dose of the same radio-active agent, temporary sterilization followed by resumption of reproductive activity may be produced. The

experiences of a number of investigators agree in this matter without, I believe, any contradictory evidence. This of course, would mean that for a time sex cells were killed or completely inactivated, but that at the end of that period active sex cells were again formed.

Perhaps the discovery of most importance to the race is that abnormality of structure within the sex cell itself can be produced by exposure to X-rays. The experiments of Mavor, Anderson, Muller, and others have shown that the mechanism by which regular distribution of the chromatin material within the sex cells is normally brought about, is frequently and fundamentally upset following exposure to X-rays. Inasmuch as fundamental morphological and physiological abnormalities involving modification of sex, sterility, and in some cases early death of the individuals are produced by such unusual distribution of chromatin, it is easy to see that a very important principle is involved. Not only do such changes in distribution of the chromosomes take place, but the appearance of many morphological and physiological variations listed by the geneticist as mutations is produced. Leaving entirely out of consideration the imperfect evidence obtained from reported abnormalities in humans, the work which Bagg and the writer have published dealing with mice is strongly suggestive of the occurrence of this phenomenon. The principle is further established by the recent work of Muller, who, because of the definite information which he possessed concerning his material (Drosophila), is in a position to procure incontrovertible evidence. Taken together, the cases listed, I believe, seem beyond any doubt to establish the direct effects of radio-active substances on sex cells.

DISCUSSION

From the above facts, certain lines of reasoning may be followed with considerable benefit. First among these is the realization that any agent producing sterilization by killing or inactivating germ cells holds the potentiality for harm. In such cases it is clear that the effects of radio-active substances upon the germ cell may be great enough to cause death, inactivity, malformation, or internal upset of the sex cell. *There is no possible way of being sure that any treatments of the gonad with radio-active substance which cause death or inactivity are not also producing in other sex cells of the same individual, malformation or internal upset.* This fact is of primary importance and cannot be safely ignored.

The three grades which lead to death, inactivity, or malformation of the sex cells are striking and immediate in their effect. They would force themselves upon the medical profession eventually whether that profession desired to recognize them or not. The upset of the internal organization of the sex cell leading to genetic change is, however, much more subtle; its effects may not make themselves felt for two or more generations, as was the case in the mice and in drosophila. Because of the fact that the life of the individual medical man does not commonly span the entire life history of two complete generations, the responsibility which he feels for remote descendants of those treated by him has not been as weighty as that felt for the patient himself or his immediate progeny. Only recently have the results of experimentation in the laboratory made it clear that in the case of treatment of the gonads of young people or those of reproductive age, it is imperative that the medical practitioner should look beyond immediate results and shape his course of action in such a way as not only to benefit his particular patient, but to insure the consideration of the remote descendants of that individual as well.

Certain criticism of this conserative point of view will undoubtedly be made. The use of radiotherapy is increasing and its rewards are lucrative. Whole journals are partisan enough to concentrate on that particular field and results which are contrary to the popular desire—that such agents be considered mild and safe—are therefore not apt to be enthusiastically received. One of the most thoughtless and sinister suggestions is found in a recent paper by Dr. M. R. Robinson in which the author cites Nurnberger and apparently agrees with him in the fact that if hereditary defects are produced which are Mendelian recessives the situation is harmless. He makes this assertion because inbreeding in humans is unimportant and relatively rare. Thus he considers that the chance of mating between two individuals who carry a recessive hereditary defect produced by irradiation, is not worthy of consideration: What he really is advocating by this suggestion is that we should not worry until such individuals have thoroughly seeded the human race with a widespread sprinkling of the defects in question. After such seeding, however, it would crop out sporadically in any locality in a manner entirely beyond our control. This would follow because every individual who carried such a trait would hand it on to approximately one-half of his progeny even though it might not appear on the surface. Another criticism advanced by Robinson shows a lack of appreciation of physiological change, during the life of a mammal, which proves his almost

complete unfitness to approach the matter from an experimental angle. It is of a type of comment altogether too common to those of the medical profession who have forgotten the foundations of scientific criticism, and consists of his expectation that repetition of a given exposure of X-ray to animals genetically different from those used in the first experiment would produce similar results to those first obtained. There is sufficient genetic variation between brothers and sisters in a single strain of mammals which have not been made genetically homogeneous by continued inbreeding so that one might fairly expect different results to follow an identical exposure to any radio-active agent. This factor of uncertainty is multiplied many times in the case of the human material, which in its very essence is highly variable. *The very fact that results of exposures to radio-active substances do not always produce the same results is one of the reasons why, in employing them, medical practitioners should proceed with the utmost caution.* The use of rays on living material is not nearly so simple as is the use of other agents commonly employed in different types of therapy.

One other point worthy of emphasis and likely to cause confusion, and one which is rarely recognized, is the fact that the average medical practitioner has not grasped clearly the distinction between transmission and heredity. From a biological point of view the term "hereditary syphilis" is a misnomer. In this case there is involved definite *transmission* of an active principle in a relatively unchanged form from one generation to another. *Heredity* on the other hand means that in some way the composition or the organization of the sex cell itself has been altered in such a manner as to produce a reflection of that change in an altered structure or function of the animals arising from that cell itself. It will be seen that constitutional tendency to susceptibility or resistance to various types of disease and the causes underlying constitutional abnormalities may be produced by a complex process of heredity although quite obviously their direct transmission would not be likely.

CONCLUSIONS

1. The germ plasm is modifiable by certain agents which affect it directly.

2. Radio-active substances are among the most powerful of such agents.

3. Any agent which kills germ cells bears the possible power of producing inactivation, malformation, and genetic changes when used in decreasing amounts or strength of exposure.

4. The duty of medical men to future generations demands that

a. accurate systems of human records be established;

b. that medical men keep up to date with advance in experimental genetics;

c. that they use extreme caution in advocating the use of agents which may affect the germ plasm in young individuals or in individuals of reproductive age.

d. that they discourage acceptance of results based on control data insufficient in number and inadequate. (In this respect the paper of Robinson before referred to in which the total experimental data consists of eight experiments, each consisting of one rabbit, is an outstanding example to be avoided.)

e. that they encourage the inclusion wherever possible of courses on experimental methods and scientific criticism in the pre-medical or medical curricula.

PROGRESS AND PROSPECT IN TREATMENT OF CANCER[1]

By ROBERT B. GREENOUGH, M.D., F.A.C.S., Boston
Chairman of the Committee on the Treatment of Malignant Diseases with Radium and X-ray

THE Committee on the Treatment of Malignant Diseases with Radium and X-ray, of which I have the honor to be chairman, has attempted to make available for study a portion of that great mass of surgical material in this country which may aid in providing an answer to some of the disputed points in regard to the treatment of cancer in its more common situations.

Any attempt to review the literature at once makes evident the fact that published reports of end-results in cancer cases from different clinics have been prepared under such different conditions that no combination of the figures presented is possible and the advantage of large numbers of cases, in eliminating individual errors and exceptions, is thereby lost. To overcome this difficulty the committee has attempted to do two things: (1) to establish a uniform method of classifying and recording cancer cases of the more important regions of the body, and (2) to establish criteria which could be accepted in every clinic in regard to the inclusion or omission of case records for consideration.

Such an effort has placed a great burden upon the individual representatives of the clinics participating in these investigations since all the hospital material for a specified period has to be reviewed and data secured and entered on the abstract cards in accordance with the committee's specifications.

To permit a minimum 5-year end-result report, the cases to be studied have been restricted to those of the calendar years 1918, 1919, and 1920. In the first investigation, that of cancer of the cervix, the period was from 1914 to 1919. In dealing with cases treated so long ago it was necessary furthermore to restrict the investigation to those clinics in which accurate records, adequate pathological service, and a complete follow-up system were, at that time, in operation.

One preliminary report on the end-results of treatment of cancer of the cervix was published in 1924, although at that time a full 5 years had not elapsed, and a follow-up of only 3 years could be obtained in the later cases.

At the present time two reports are in preparation: (1) the cervix cases are being carried to a minimum 5-year end-result, and (2) material for a report on cancer of the breast on a minimum 5-year basis is being analyzed. Abstract cards for three other forms of cancer have been prepared and the collection of records for cancer of the mouth and tongue, cancer of the rectum, and cancer of the ovary has been begun. Similar cards for cancer of the colon and of the thyroid are in preparation.

To this very brief statement of the activities of the committee, I should add my appreciation of the cordial co-operation, which has been obtained on all sides, in the arduous and time consuming labor of looking up and abstracting case records and in securing the necessary data on the end-results; a burden which falls, as a rule, upon the younger members of the surgical fraternity, but one which is essential if accurate knowledge of the results of treatment is to be obtained.

That some such accurate statistics of the results of the different methods of treatment of cancer are greatly needed, is evident today on every hand. The medical world universally accepts surgery and radiation as effective methods of treatment for cancer; and while a multitude of other methods has been advocated from time to time, some undoubtedly in all good faith and others unfortunately for less worthy motives, none of these other methods of treatment has as yet gained the confidence of the medical profession. Even as regards the value of surgery and radiation there are honest differences of opinion among those well qualified to judge, and it is to secure information for the better appraisal of these methods that the work of this committee has been undertaken.

The past few years have seen a number of advances in our knowledge of the biology and of the pathology of cancer, but the cause or causes are still unknown to us and the prospect of a specific remedy for the disease appears to be as far away as ever. We can go further and state that even if such a specific remedy were to be developed, as in the case of diphtheria or malaria, the problem would still be far from solution, for it is well known that even these diseases must be recognized in the early stages if the specific treatment is to be curative.

It is the difficulty of the recognition of the early case of cancer both by the patient and by his physician which is chiefly to blame for its high mortality. That surgery can cope with the

[1] Report presented at the Clinical Congress of the American College of Surgeons, Detroit, October 6, 1927.

disease in its early stages is abundantly demonstrated in many regions. The fact that from 70 to 90 per cent of cases of breast cancer can be cured, if operated upon during the early and local stage of the disease before the axillary lymph nodes are affected, is sufficient evidence of the truth of this statement. Unfortunately, such early and favorable cases include only about 25 per cent of the cases of breast cancer that enter our general hospitals; and the prospect of cure in the other 75 per cent becomes progressively less and less with the longer delay and the wider extension of the disease.

These are the facts which justify the campaign for the education of the public which is sponsored by The American Society for the Control of Cancer. An awakening of the public mind to the recognition of suggestive symptoms and to the danger of delay is undoubtedly the first consideration. This education alone, however, will not solve the problem. An educated public has a right to demand an educated medical profession and there are too many practitioners who still follow the "wait and see" policy in a doubtful case, and thus permit the disease to extend from the favorable to the incurable stage before their very eyes.

The fact is that cancer today is not a one-man job. It requires all the resources and all the professional talent of a large general hospital to deal with the disease in its many situations.

In my own state (Massachusetts), under an energetic public health commissioner, supported by the legislature and by a governor who recognizes his reponsibility for the health of the community as well as for its material welfare, a system of twelve special cancer clinics is being organized in the larger general hospitals scattered throughout the state. In each of these clinics a group of physicians is available who are competent to deal with cancer in all its situations and equipped with material resources to treat all stages of the disease. Such service may be rendered free to the poor patient or a moderate fee charged to those who are not in need of charity. The work of these clinics is co-ordinated with a central state cancer hospital of seventy-five beds, which again is equipped with staff and personnel to deal with cancer in all its forms. We believe that such facilities cannot fail to add to the prompt and effective treatment of the disease in Massachusetts.

With an educated public and with competent professional ability to deal with early and doubtful cases near at hand, a great stride has been made in the utilization of our available resources against cancer. Unfortunately, however, there is room for improvement in the application of treatment, both surgical and radiological, in many cases. Thirty per cent of the cases of cancer of the breast coming to the Huntington Hospital for treatment of recurrence after operation are found, upon investigation, to have had performed originally an operation which falls far short in extent of the recognized limits of the radical operation for cancer of the breast. The reasons for the failure of the surgeon to give to his patients the chance every case should have, of being cured by radical operation, are hard to understand, but I suspect that apathy or pessimism as to the probability of cure are the most frequent motives. Inadequate operations of this sort are being performed today in many of our hospitals and it is this fact, as much as anything, which justifies the segregation of the cancer material of the hospital in the hands of a group of men who are interested and willing to give their whole activity to the welfare of the cancer patient.

What is true of the surgical treatment of cancer is likewise true of its treatment by X-ray and radium. Not every patient obtains treatment from a radiologist whose greatest interest is in therapy. Many treatments are given with inadequate apparatus and many in a perfunctory manner that offers little advantage to the patient. Especially in regard to radiation therapy is to be noted the frequent lack of accurate records and of an effective follow-up system. It is again these facts which justify the special cancer service in the general hospital where the X-ray and radium therapeutist can join with the surgeon, the pathologist, and the specialists in other branches of medicine, in consultation and co-operation, with a view to giving to each individual cancer patient the treatment or the combination of the methods of treatment best suited to that individual case.

Fig. 5. Chronic benign gastric ulcer with perforation in the lesser curvature near the pylorus.

Chronic Ulcer of the Duodenum and Stomach.—John B. Deaver.